Growth and Stagnation in Developing Economies: a Structural Approach

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This dissertation is submitted for the degree of Doctor of Philosophy

Declaration

This thesis is submitted according to the requirements of the Degree Committee of Land Economy. It does not exceed the regulation length of 80,000 words including footnotes, references and appendices. It is the result of my own work and includes nothing which is the outcome of work done in collaboration with others, except where specifically indicated in the text and Acknowledgements.

It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution except as declared in the Preface and specified in the text. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University of similar institution except as declared in the Preface and specified in the text.

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Summary

During the 2000s, after almost two decades of poor growth performance, Latin American countries have experienced a period of growth acceleration. Even though it has been led mainly by a faster growth of external demand for natural resources, this demand has increased national income, and, by increasing wages and investment, it has recovered domestic markets. Nonetheless, even in face of a more diversified demand, Latin American countries have specialised in the production and exports of less technologically advanced goods, increasing the asymmetry between the structures of demand and supply. This dynamics contrasted with the pattern followed by East Asian developing economies, where the strategy of development for production and trade has focused on technological upgrading. As the demand for high-tech manufacturing has increased, these countries have sophisticated their structure of production and promoted exports of high-tech goods.

With the aim of analysing the long-term consequences of these different patterns of production and trade specialisation, this study considers a Kaldorian approach, in which growth is demand driven and strictly related to sectoral specificities. Based on this perspective, it seeks to identify which sectors are capable of promoting higher long-term growth rates and the mechanisms through by this process take place. The study shows that specialisation in sectors with both high dynamic increasing returns and high income elasticities can trigger a cumulative causation growth process. Additionally, countries' structures of production and trade are analysed through input-output methods to assess to what extent the Latin American growth pattern is sustainable in the long run. The impacts of countries' trade liberalisation and the effects of their integration into global supply chains is compared across countries with the aim of evaluating which ones that are benefiting the most from these changes in commercial structure and which are losing sectors crucial to promote high and sustained growth rates.

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Introduction

After nearly two decades of virtual stagnation, during the 2000s Latin American countries have experienced a significant period of growth acceleration. According to the World Bank – World Development Indicators (WB-WDI), between 1980 and 2002, Latin American developing countries' income per capita grew by 0.2% per year, whilst between 2002 and 2008 this growth rate increased to 3.2% per year. Besides having experienced a substantial acceleration of income growth, which contrasted to previous years, these countries have profited from a significant decline in unemployment rates and an increase in public and private investment rates. The unemployment rate in the region dropped from 9.1% to 6.4% between 2002 and 2008, and the investment rate (measured as gross fixed capital formation as percentage of GDP) increased from 17.3% to 21.3%, with special regards to public investment, which has risen from 3.0% of GDP, in 2002, to 4.6%, in 2008.

This growth period, on the one hand, occurred in parallel with a rapid growth in the world economy, when these countries' terms of trade appreciated, their capital inflows increased, and external demand become stronger, especially the demand for natural resources. On the other hand, increasing wages, decreasing unemployment rates and increasing public and private investments led to the recovery of the domestic market as an important source of demand. Consequently, even though external demand for natural resources contributed significantly to these countries' growth acceleration, domestic demand, which tends to be more diversified in terms of its sectoral structure, was also an important component of this growth acceleration process.

Nevertheless, whereas these economies' sources of demand became stronger and more diversified over this decade, their production structure did not appear to move in the same direction. Despite increasing considerably for the economy as a whole, domestic production was not sufficient to absorb part of this increase in demand in some sectors. As a result, imports increased significantly, especially in the most technologically advanced sectors. Between 2002 and 2008, Latin American imports of goods and services presented a generalised increase, rising from 21.8% to 26.0% of GDP. However, whilst high-tech imports accounted for 60.0% of Latin American trade imports, high-tech exports accounted for only 33.6% of international sales[1].

This process has stressed the asymmetry between the structures of demand and supply in Latin American countries. Even though demand has increased in a wide range of sectors, especially due to an increase in domestic markets, Latin American economies have specialised in the production and exports of less technologically goods. These dynamics contrast to the pattern followed by other developing countries, such as the East Asian economies. These countries increased their specialisation in manufacturing activities, with special regards to those sectors with high technological content. Consequently, in contrast to Latin American countries, where the share of high-tech exports diverge from the share of high-tech imports, East Asian low and middle income countries' high-tech exports accounted for 53.3% of trade exports in 2008, and high-tech imports accounted for 50.6% of trade imports[2].

To understand the consequences of these different patterns of production and trade specialisation, this study will consider a Kaldorian approach for countries' growth processes, which is demand driven, cumulative and related to sectoral specificities. Considering that some sectors might present low dynamic increasing returns to scale and reduced income elasticities of demand, from the Kaldorian perspective, specialisation in this group of sectors will reduce countries' long-term growth rate. Conversely, specialisation in sectors that present the highest dynamic increasing returns and the highest income elasticities will promote countries' growth acceleration. Therefore, this research investigates the importance of the sectoral structures of production and trade to promote high and sustained growth rates with the aim of evaluating countries' growth patterns. Moreover, the structures of production and trade of developing countries will be analysed through input-output matrices to assess to what extent Latin American growth in the 2000s is sustainable in the long run.

This work is divided into two main sections. The first section is dedicated to understanding the importance of the sectoral structure of production and trade to

[1]Latin American low- and middle income-countries' imports and exports from/to outside the subcontinent. High-tech sectors are classified according to UNIDO (2013:205) classification, which is based on International Standard Industrial Classification (ISIC), Revision 2. It includes divisions 24, 29 to 34 and 35 (excluding group 351). Data is available at United Nations COMTRADE Database (UN-COMTRADE).

[2]East Asian low- and middle-income countries' imports and exports from/to outside the subcontinent.

guarantee high growth rates based on the Kaldorian approach. This section seeks to identify the sectors capable of promoting the highest growth rates in the long run. The second section assesses the impact of the countries' trade liberalisation during the 1990s and 2000s on sectoral output, as well as the effects of countries' integration into global supply chains. This section compares these impacts sectorally across countries to evaluate which ones are benefiting the most from these processes and those that are losing sectors essential to the promotion of high and sustained growth rates.

The first section is divided into four chapters. Chapter 1 discusses the importance of considering structural changes to understand countries' economic dynamics from a Kaldorian perspective. Although Kaldor was not the first author to consider this aspect, his systematisation is an important starting point to analyse the relation between countries' growth and their productive and commercial structures. The understanding of this approach is crucial to address the main issue of this thesis, i.e.: to what extent the growth pattern followed by Latin American economies in the 2000s is capable of promoting high growth rates in the long run. Thereby, this chapter provides the theoretical basis for the subsequent chapters of the first section.

The following chapter seeks to analyse the impacts of a faster growth of developing economies on long-term growth rates of natural-resource exporters. The Balance-of-Payments Constrained Growth (BPCG) model is modified to account for the impact of different growth rates among trading partners with specific structures of demand. Because low- and middle-income countries have been growing faster than high-income countries since the 1990s, and the former group demand relatively more natural-resource-based products than the latter, this process might have benefited those countries which export predominantly these products. The aim of the chapter is to assess to what extend a growth pattern based on these exports, such as the one experienced by Latin American countries, is able to promote sustained high growth rates.

Chapter 3 investigates the reason why productivity growth rates differ between countries and regions in different stages of development. According to the Kaldorian approach, sectors have different degrees of dynamic increasing returns. Consequently, total productivity grows faster in some countries due to their sectoral structure of production. In this vein, Verdoorn's law (the long-term relationship between output growth on productivity growth) is estimated to evaluate those sectors capable of providing more rapid productivity growth according to countries' income level.

The last chapter of the first section, Chapter 4, seeks to address the long-term implications of the sectoral differences in the degree of dynamic increasing returns and income elasticities of demand for countries' growth. In this chapter, despite being the determinant of countries' growth in the long run, income elasticities of demand are considered partially endogenous to countries' growth rates due to the existence of dynamic increasing returns to scale. This chapter presents a sectoral model with cumulative causation to explain the importance of structural change for countries' long-term growth. Moreover, based on the findings of Chapters 2 and 3, this model is applied to identify which sectors are able to promote faster growth rates. Essentially, it shows that although Kaldor has stressed the importance of structure of production and trade for growth, Kaldorian growth models do not fully incorporate these issues. In this vein, a model that contemplates them is necessary to explain how sectoral specialisation can trigger a cumulative causation processes in open economies.

The second section is divided into Chapters 5 and 6. In the first chapter of this section, changes in countries' production structures, as well as changes in demand absorption, are investigated using Structural Decomposition Analysis (SDA). The chapter presents a method to decompose changes in countries' intermediate consumption into technological changes and substitution of imported inputs. The aim of this decomposition is to identify to what extent substitution of imported for domestic inputs have reduced output growth across sectors, and compare it with the positive impact of exports growth. This analytical tool is relevant in order to provide a sectoral investigation of developing countries' trade liberalisation during the 1990s and 2000s. Countries' patterns of specialisation are addressed with the aim of assessing which sectors have benefited from the removal of tariff and non-tariff barriers.

Chapter 6 seeks to evaluate to what extent countries' engagement into Global Value Chains (GVC) have affected their productive and commercial structures, and what are the consequences of this process for economic growth. This chapter presents a technique to evaluate the impact of countries' vertical specialisation in the domestic content of exports, and it is contrasted to the positive impact of market share growth that this fragmentation process might have promoted. The net impact for each sector's production chain is compared among countries to assess which sectors have contributed the most in each case. Based on the findings of the first section on the capability of different sectors to promote growth, countries' potential to reach high and sustained growth rates in the long run is analysed.

This work finishes with an additional chapter dedicated to providing the concluding remarks. Besides presenting the main conclusions of the thesis, with special regards to its consequences for Latin American economies, this chapter discusses the importance of promoting selective industrial policies to guarantee structural changes towards those sectors capable of triggering a cumulative causation process of increasing growth rates.

Chapter 1

A Survey on the Kaldorian Approach for Structural Change and Cumulative Causation

1.1 Introduction

One of the most important issues in economic theory is why some developing countries were able to reduce the income gap to developed economies and others were not. Economic historians present many examples of countries that were able to catch up and reduce the income gap, such as the USA and Germany during the nineteenth century, Japan in the mid-twentieth century and, more recently, the Asian Tigers (South Korea, Taiwan, Hong Kong and Singapore). However, probably the most common cases are those countries that have failed to reduce the income gap to developed countries. Thereby, from a historical perspective, neither convergence nor divergence is the rule in economics.

Essentially, to understand why some countries were successful in this catching-up process (and why others have failed). one has to investigate the reason why growth rates differ between countries and regions in different stages of development. Many different approaches have addressed this issue. On the one hand, neoclassical and new growth theories assert that the explanation for the differences between countries' growth rates is related to the availability of production factors and their allocation, which characterises a supply-oriented approach. On the other hand, the Keynesian perspective emphasises the relevance of effective demand as a primary driver of accumulation, and thus the long-term growth rate is demand driven.

With some notable exceptions, however, none of these approaches take explicitly into account one of the most evident characteristics of the catching-up processes. Looking at those countries that were able to reduce the income gap to the most developed economies, an evident similarity is the process of structural transformation. More specifically, this is the process of moving the structure of production and trade from some specific sectors to others. As Pasinetti (1993) has noted, although classical authors have paid some attention to the importance of structural dynamics for economic growth, economists have virtually neglected this aspect since the marginal revolution. Adam Smith, for example, stressed that an increase in the share of 'productive' work (in contrast with 'unproductive' work) was at the root of a process of economies' expansion. Marginalists and subsequent neoclassical models, on the other hand, considered factor allocation as the central explanation for countries' growth, and, consequently, they viewed structural changes and the learning process as secondary issues. Pasinetti also argues that even the modern dynamic macroeconomic models were compelled to abandon any hypothesis of change in structure. According to him, early Keynesian growth models, such as Harrod-Domar model, and the subsequent Post-Keynesian models hardly incorporate structural changes as a driving force for economic growth, even though they recognise their importance.

Despite being neglected by the main core of economic models, structural changes and their relation to economic dynamics is at the root of those views that accounted for historical facts to understand the process of countries' development. Kaldorian and structuralist approaches, for example, present significant contributions in favour of specialisation in modern sectors to promote growth. They show that specialisation in manufacturing activities is essential to promote a cumulative process of increasing growth rates, whereas specialisation in primary goods may negatively affect total productivity growth and lead to a balance-of-payments crisis, constraining countries' long-term growth rates. These approaches argue that the relation between structural change and economic growth is an important issue and it cannot be neglected in understanding countries' growth in the long run. Nevertheless, the vast majority of economic growth models are constructed assuming a single sector. Based on this assumption, they try to identify general factors, such as R&D and educational spillovers, that have led developing countries to achieve higher growth rates and reduce the income gap, as well as those that have led high-income countries to keep growing faster, increasing the income differential to low- and middle-income countries.

Although the importance of these general factors is not negligible, one important issue that has to be taken into account is that the potential of these factors to enhance growth varies among sectors. Spillovers from research activities, for example, might be more important in technology-intensive sectors than in sectors intensive in labour or natural resources. Thereby, in order to understand why some countries were able to reduce the income gap and others have failed, it is crucial to comprehend how different sectors play different roles in the dynamics of growth, focusing on their specific contributions to the different stages of development.

This chapter provides some empirical evidence and the theoretical basis for this analysis, seeking to explain how this issue was addressed in the economic literature. It aims to present the main framework of the Kaldorian approach for the relation between economic growth and structural dynamics, with some insight into other approaches, such as the neo-Schumpeterian and the structuralist.

The chapter has eight sections. After this introduction, in the next section, some stylised facts are presented to show how inter- and intra-sectoral structural changes are relevant to explain long-term growth rates for countries in different stages of development. Section 3 discusses the basics of the Kaldorian approach in contrast with the neoclassical and new growth theories. These differences are important in understanding how the sectoral approach will be taken into account during this work. Section 4 addresses the impacts of transferring labour from sectors with low levels of productivity to modern sectors. This section highlights the importance of these changes to overall productivity growth for low-income countries, as well as its limitation for middle- and high-income countries. Section 5 discusses the technological gap literature from a sectoral perspective, highlighting its relevance to reducing the differential of productivity levels and, thus, to promoting a catching-up process. Section 6 presents the Kaldorian approach to explaining why productivity diverges among countries due to different sectoral specialisations and how this issue is relevant to explaining a cumulative causation process. Section 7 analyses how sectoral differences are important to explain growth rate divergences focusing on the Kaldorian models for open economies, i.e., the Export-Led Cumulative Causation (ELCC) and Balance-of-Payments Constrained Growth (BPCG) models. Finally, the last section presents a systematisation of this discussion, addressing the need for a sectoral approach to explain a cumulative process of growth in open economies, which will be the aim of this work.

1.2 Stylised facts on structural change and growth dynamics

Even though the relationship between structural change and economic growth is not a new issue in economics (it was focused by the classics, such as Adam Smith, as stressed by Pasinetti, 1993), in the 1940s and 1950s many economic theories (inspired by historical evidence) have emerged to explain the importance of industrialisation for growth. This group of theories, usually associated with the structuralist approach, advocates that an increase in the share of industrial activities promotes economic growth through certain mechanisms. They argue, for example, that productivity level is greater in industrial activities (Lewis, 1954), that industry has higher forward and backward linkages (Hirschman, 1958) and, once this sector presents increasing returns to scale, rather than diminishing returns, such as primary sectors, that industrialisation promotes a circular process of cumulative causation (Myrdal, 1957)[3].

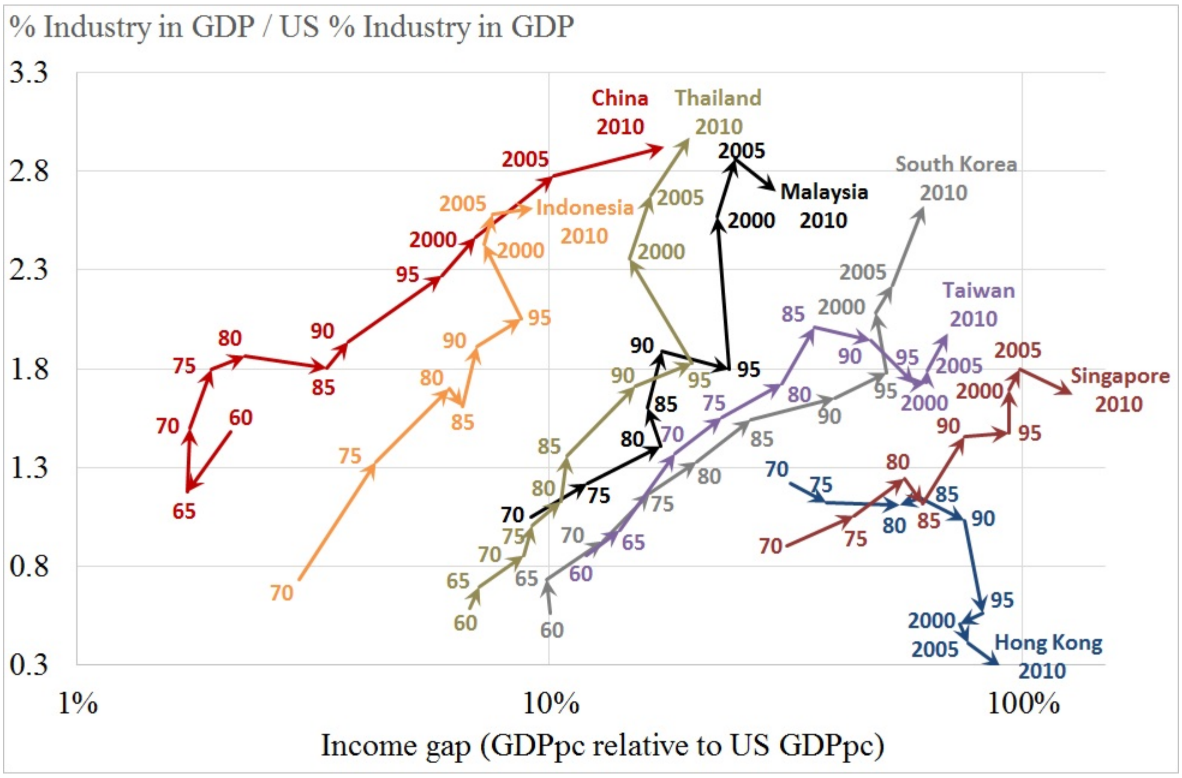
More recently, since comparable data for developing countries has become available, there has been a large number of works that addressed this issue, and showed the importance of the dynamics of sectoral composition of production and trade in promoting growth in the long run. Szirmai (2012), for example, presents strong evidence that manufacturing is the engine of growth in developing countries. According to the author, there are no important examples of countries that have experienced success in economic development without a strong industrial base.

Figure 1.1 shows how the degree of industrialisation is related to the income gap for those countries that have reduced the income differential to the United States the most. In the vertical axis, we have the relative degree of industrialisation, measured as the share of total industry in the GDP of the country under consideration divided by the same variable in the US. In the horizontal axis, we have a measure for countries' income gap to the US (presented in logarithmic scale).

The figure presents data for all those countries that reduced the income gap to the US at least by half between 1960 and 2010. They were China, Indonesia, Malaysia, Thailand, South Korea, Taiwan, Singapore and Hong Kong. It is clear that these two variables are strictly related. In all cases but Hong Kong, periods of faster reduction of income gap are those when the relative degree of industrialisation has grown faster.

[3]For more details on the importance of manufacturing in the structuralist approach, see Rocha (2015).

Figure 1.1: Income gap and degree of industrialisation relative to the US (1960-2010)



Sources: GGDC and PWT 7.1; author's elaboration

In China, for example, from 1990 to 2010, the industrial share in GDP has grown from 1.9 times the US's share to 3.0 times, and the relative income was reduced from 3.7% to 17.4%. The Chinese case is not different from Taiwan between 1960 and 1985, from Singapore, Korea, Thailand and Malaysia between 1965 and 2010 (with exception of some periods, such as 1995-2000, when these countries were affected by the Asian crisis), and from Indonesia during the 1970s and between 1985 and 1995. All these countries have experienced a fast income-gap reduction simultaneously with an increase in the relative degree of industrialisation.

The Korean case is the one in which this relation between the share of industry in GDP and gap reduction is probably the clearest. From 1965 to 2010, Korea experienced a virtually constant income-gap reduction and a constant increase in the relative degree of industrialisation. In 1965, Korean income per capita (in PPP) was one tenth of the US income, and its industrial share in GDP was 0.73 of the US's share. In 2010, Korean income increased to 63% of the US income, which means that the gap has reduced by 84%, and, simultaneously, its industry increased to 37.9% of GDP, becoming relatively 2.6 times larger than US industry.

The relationship between industrialisation and a faster increase of income becomes even clearer when countries that were able to reduce the gap to the US during a certain period but could not sustain it are taken into account. Table 1.1 compares the periods of faster reduction and increase in the gap of the three largest Latin American economies (Argentina, Brazil and Mexico[4]) and Asian economies (China, South Korea and Indonesia[5]). As can be seen from this table, the importance of structural change towards industrial activities is evident.

Table 1.1: Income gap and industrial share in GDP: specific cases (1960-2010)

Country	Period	Gap reduction (in %)	Industrial share in GDP		
			Initial year	Final year	Difference
Brazil	1967-1980	43.5%	33.9%	43.8%	10.0 p.p.
	1980-1994	-47.4%	43.8%	40.0%	-3.8 p.p.
Mexico	1966-1981	29.9%	26.1%	31.4%	5.3 p.p.
	1983-1995	-44.4%	45.6%	32.4%	-13.2 p.p.
Argentina	1974-1990	-72.1%	39.3%	34.2%	-5.1 p.p.
China	1990-2010	78.5%	38.1%	42.4%	4.3 p.p.
South Korea	1962-1996	82%	17.0%	32.6%	15.6 p.p.
Indonesia	1967-1981	62.6%	13.3%	38.4%	25.1 p.p.

Sources: GGDC and PWT 7.1; author's elaboration

The relationship between gap reduction and industrial share in GDP is valid not only in those periods in which countries have reduced the gap, but also when the income gap has increased. During the periods when countries have experienced a faster reduction in the gap, the share of industry in GDP has increased more significantly. On the other hand, those periods in which the income gap to the US has increased are associated with a reduction of the degree of industrialisation. In Brazil, the contrast of these processes is very clear. From 1967 to 1980, the income gap to the US reduced by 43.5% (Brazilian income increased from 16.3% to 28.7% of the US income), whilst the industrial share in GDP increased from 33.9% to 43.8%. Nevertheless, from 1980 to 1994, the Brazilian relative income dropped by 32.2% (in 1994 it reduced to 19.4% of the US income) and the industrial share in GDP not only stopped increasing, but decreased by 3.8 percentage points (p.p.).

This situation is not different from those experienced by the other Latin American

[4] These periods are the ones the countries presented the faster growth rates in gap reduction or the faster growth rates in gap increases. Because there are breaks in the industrial series of Mexico and Brazil in the years 1983 and 1994, respectively, these years are used to avoid comparing series obtained by different methodologies.

[5] Although the Indian economy is larger than Indonesia, this country was not considered because it did not have any long period of gap reduction or increase.

countries. In Argentina, from 1974 to 1990, and in Mexico, from 1983 and 1995, the relative income to the US reduced significantly, simultaneous to the degree of industrialisation. Furthermore, in Mexico, from 1966 to 1981, as well as in the East Asian economies for the periods presented in the table, the share of industry in GDP grew in parallel with the income gap reduction. Therefore, the degree of industrialisation and the relative income are strictly correlated for those economies that are catching up, as well as for those that are falling behind.

This relationship has shown that industrialisation is an important issue to be considered when convergence and divergence processes are analysed. Until now, however, the analysis has focused on the importance of moving from other sectors towards industry as a whole. Not surprisingly, when intra-sectoral changes are taken into account, a similar pattern is verified. Figure 1.2 shows the relationship between the relative technological intensity of manufacturing production and the income gap for the same countries analysed previously[6]. The horizontal axis, such as in Figure 1.1, presents the income gap to the US, measured as the relative income per capita. The vertical axis presents the relative technological intensity of manufacturing production, which is measured by the share of high-tech (HT) industries[7] in total manufacturing value added relative to the US.

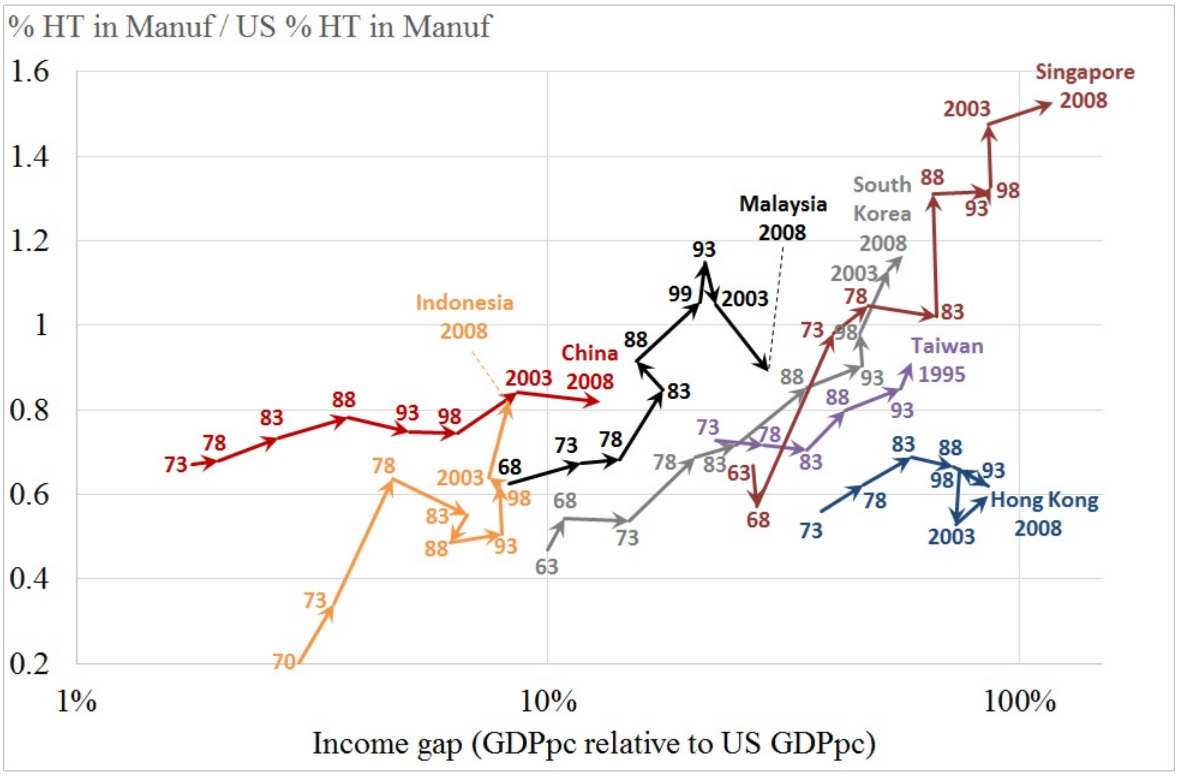
From the figure, it is clear that reduction in the income gap is directly related to an increase of the share of high-tech industries in total manufacturing, suggesting the importance of intra-sectoral structural change for growth. In all analysed cases (now even in Hong Kong), the periods of the faster reduction in income gap are those associated with a higher increase in technological intensity. This relationship is especially interesting because it seems to be more important for those countries in advanced stages of development. As can be seen from Figure 1.2, South Korea is again a clear example. From 1968 to 2008, it significantly reduced the income gap to the US, and, simultaneously, increased the share of high-tech manufacturing industries. Notwithstanding, the faster the increase in South Korean technological intensity of manufacturing value added, the faster its income growth relative to the US was.

A comparison between Singapore and Hong Kong shows explicitly the importance

[6]Thailand was excluded from the graph only to make it more clear, but the country follows a pattern very similar to Malaysia.

[7]High-tech industries includes Chemicals, Machinery, Electrical and Transport (divisions 24, 25 and 29 to 35 in the ISIC, Rev. 2). This aggregation is based on UNIDO (2013:205) classification, but it includes division 24 and group 351 due to classification constraints at the UNIDO-INDSTAT2 database.

Figure 1.2: Income gap and technological intensity of manufacturing (1963-2008)



Sources: UNIDO-INDSTAT2 and PWT 7.1; author's elaboration

of technologically intensifying countries' production structures. Both countries presented around the same income from 1973 to 1988, growing at similar rates. Singapore, however, kept increasing the share of high-tech manufacturing industries after 1988, whilst in Hong Kong, it stopped increasing. Consequently, whereas the latter was unable to reduce the gap to the US after 1993, the former kept increasing its relative income, which rose from 85% to 146% between 1993 and 2008. Hence, Singapore becomes the only country (of those under consideration) that has been able to overtake the US income.

This relationship between income growth and the technological intensity of production shows that not only inter-sectoral structural changes, such as moving from agriculture to industry, are important in promoting faster growth rates, but also intra-sectoral structural changes. Moreover, it shows that moving the structure of production towards high-tech industries is especially relevant to explain faster growth rates in middle- and high-income economies, such as in the cases of South Korea and Singapore. A relative increase in the share of high-tech products in total manufacturing is strictly related to faster growth rates for those countries in more advanced stages of development.

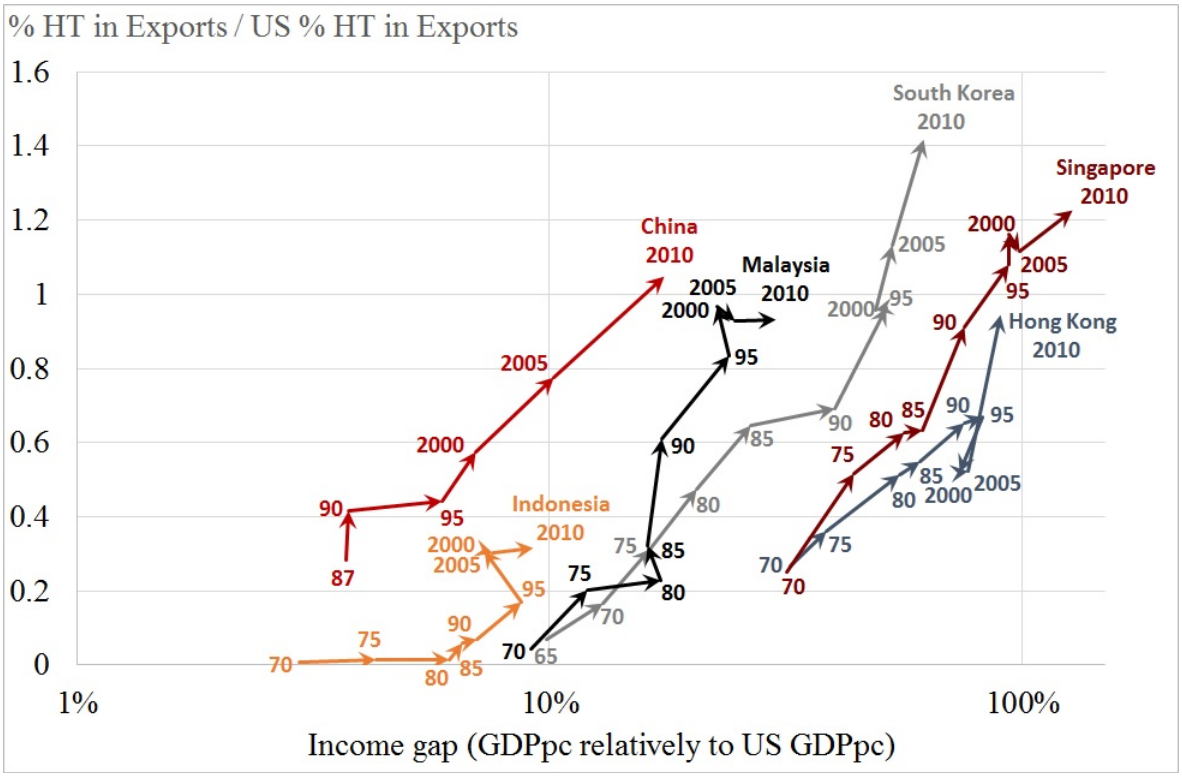
The relation between technological intensity and economic growth in the long run is not restricted to countries' structures of production. Technological intensity of trade also embodies a close relationship with high and sustained growth rates. Addressed originally by the early Latin American structuralists, the structure of exports and imports has been an important explanation for the uneven growth rates among countries. Prebisch (1952) argued that because income elasticities of demand for primary goods is lower than one, and for manufacturing it is higher, as countries' incomes per capita grow, the demand for more technological goods increases faster than for primary goods. Consequently, the relative price of the latter decreases and those countries that export predominantly these products face balance-of-payments crisis due to a long-term deterioration of their terms of trade. Furtado (1961) presents a complementary explanation for natural resource exporters' underdevelopment. According to him, economic development is a process of incorporation and diffusion of new technologies. However, these countries produce predominantly through imported capital inputs, which reduces their capability to assimilate technologies embodied in these goods. Consequently, they are unable to promote economic development through innovation.

Recently, many studies empirical studies have advocated that export composition is crucial to promoting sustainable growth rates in the long run. Berg, Ostry, and Zettelmeyer (2012), for example, showed that export product sophistication (measured by manufacturing share in exports) tend to predict prolonged growth. It has been argued that product export shares of the more complex products are positively related with countries' income, as sophisticated goods hold a vast amount of productive knowledge (Felipe *et al.*, 2012; Hausmann, Hidalgo *et al.*, 2011). Thereby, technologic sophistication in trade has been addressed as a central issue to explaining divergence in countries' growth rates.

Figure 1.3 presents, in the vertical axis, countries' relative technological intensity of merchandises' exports and, in the horizontal axis, income per capita in relation to the US for those countries that reduced the gap to the US by at least half. A clear relationship can be seen between these two variables: the higher the relative technological intensity of exports, the lower the income gap.

The fast growth experienced by Malaysia, South Korea and Singapore from 1970 to 1995 is clearly related to an increase in high-tech exports. These countries started, in 1970, with a relatively low technological intensity of exports (lower than 0.3 times the US's intensity) and increased it by more than 0.8 times in 1995. Even Hong

Figure 1.3: Income gap and technological intensity of merchandise exports (1965-2010)



Sources: COMTRADE and PWT 7.1; author's elaboration

Kong experienced the same trend during this period, even though on a lower scale. Technological intensity of exports in Hong Kong increased from less than 0.3 times the US's intensity to almost 0.7 times in 1995.

Chinese growth from 1990 to 2010 is also clearly related to the increase in technological intensity of exports. Different from the results for the technological intensity of manufacturing production, where China presented a high but constant level during this period, the share of high-tech in Chinese exports was 0.4 times the US's share in 1990, and, in 2010, it overlapped it, as can be seen from Figure 1.3.

These stylised facts on trade and production show that a process of structural change towards industrial activities is crucial to explaining countries' growth rates in the long run. More specifically, it shows that high and sustained growth rates are strictly related to the increase of high-tech products in manufacturing output and trade, especially for countries in more advanced stages of development. In the next sections, some theoretical approaches, mainly based on historical evidence, will be presented to explain this relationship between inter- and intra-sectoral structural change and economic dynamics.

1.3 Convergence and divergence in supply and demand approaches

Although classical economists have contributed significantly to understanding the reason why some countries grow faster than others, the first dynamic macroeconomic model of economic growth was developed by Harrod (1939) and Domar (1947). Despite being developed separately, both models tried to address the same basic questions: what are the investment and saving growth rates capable of maintaining a growing economy in equilibrium, and what is the economic growth rate compatible with this equilibrium? Because the Harrod-Domar growth model did not consider explicitly a self-adjustment mechanism, it was the basis for both the supply- and demand-oriented approaches developed by Neoclassical and Keynesian economists.

Neoclassical models (Solow, 1956; Swan, 1956) solve this issue by assuming diminishing returns to factors of production (rather than constant returns to capital, such as in the Harrod-Domar model) and that savings are exogenously determined by the propensity to consume. In these models, because all countries have access to the same freely available technology, countries' income gaps tend to reduce in the long run, bringing the notion of convergence. Because capital has diminishing returns (due to the assumption of constant returns to scale and convex production functions), poor countries have higher marginal productivity of capital than the rich ones. Consequently, once economies have access to foreign capital and foreign markets, which guarantees access to international funding[8], countries' income levels tend to convergence in the long run. Only continuous technological changes could explain the long-term difference between countries' growth rates in neoclassical models. However, they treat the determinants of technological change as exogenous, and thus they do not explain the persistent differences in growth rates between countries, as well as why countries' incomes have not converged (McCombie, 2006).

In the late 1980s, Romer (1986, 1990) and Lucas (1988) criticised these "old" growth models arguing against the constant returns to scale assumption and its immediate result: exogenous technological progress. This critique was the basis for the "new" or "endogenous" growth models, which assumes that productivity growth is endogen-

[8]Once countries access international funding, investments flow to those countries where marginal productivity is the highest. Hence, poor countries receive investments from the rich ones.

ously determined by output growth and that technology is an excludable good. In these models, technologies are not viewed as manna that falls from heaven. Instead, they are produced during the growth process, and the access to technology is costly. This assumption has shifted the focus of the neoclassical models from exogenous technological changes to the externalities generated by the process of capital accumulation. Consequently, in contrast to "old" generation models, these models might explain the historical divergence in countries' income[9].

These growth models can be organised in two basic groups. Firstly, the AK models, first developed by Romer (1986), which consider that capital is subject to constant returns. Hence, rather than convergence among countries, they predict countries growing at different (but constant) rates. Secondly, the models developed by Lucas (1988) and Romer (1990), which assert that production stimulates other activities, such as R&D. By assuming technology (and knowledge in general) as an excludable good, rather than available freely to everyone, they allow for the existence of increasing returns to scale in the production process[10]. Hence, growth is treated as an endogenous process, and divergence among countries is explained by the growth process itself, rather than exogenously, such as in neoclassical models.

Although these changes have been essential to bring countries' growth back to the debate in mainstream economics, these models have provided limited contributions to the understanding of the reasons why some developing countries were able to catch up and the vast majority were not. According to Palma (2005), in spite of being activity-specific, "endogenous" growth models are sector indifferent. Essentially, countries' growth rates are explained by the existence of increasing returns in activities, such as R&D and education, but they are not associated with the size of one specific sector, such as manufacturing, agriculture or services. Furthermore, according to McCombie (2002) and Dutt (2006), "endogenous" growth models, besides ignoring the role played by different sectors in the economy, neglect the importance of factors determining the growth of demand. Although they take into account the existence of increasing returns to scale, productivity growth is ultimately constrained by the growth of factor inputs, which are exogenously given. According to Dutt (2006), in these models, the

[9] Empirical evidence on convergence and divergence hypothesis is very controversial. Barro (1991) and Mankiw *et al.* (1992), for example, provide evidence that low-income countries tend to grow faster than rich countries, which suggests convergence. On the other hand, Durlauf and Johnson (1995) present empirical evidence that different regimes may take place when countries are divided into more than two groups, which supports the notion that countries' income per capita might diverge in the long run.

[10] For more details about these models and the differences in explaining convergence and divergence processes, see Aghion and Howitt (2009) and Barro and Sala-i-Martin (2004).

economy is always in full employment and thus all savings are invested. The market mechanisms solve the problems of unemployment and aggregate demand does not deviate from aggregate supply in the long run. Hence, investment is not determined by aggregate demand in the long run, but exclusively by savings.

In contrast to neoclassical and new growth theories, Kaldor (1967) stressed the importance of the interaction between supply and demand in explaining the differences between countries' growth rates. According to him, these differences are likely to be endogenous and determined by the capacity of a country to transform the demand stimulus in productivity growth. Although some changes in demand originate from changes in supply, most frequently it is supply that responds to changes in demand. Thus, countries' growth rates are primarily governed by the growth of effective demand, instead of being resource constrained, as suggested by the neoclassical and endogenous growth models.

Kaldor (1970) also highlights the importance of exports in determining growth. The primary source of autonomous demand is exports, and by means of the Hicks' super-multiplier, this demand from abroad generates other sources of domestic demand. Hence, external demand is key to understanding why growth rates differ across countries.

Furthermore, a central point stressed in this approach is the role of increasing returns to scale and its consequence for a cumulative causation process. The explanation of why certain regions have become more industrialised is the cumulative advantages accruing from industrial growth itself. Consequently, to understand divergence and convergence among countries, specificities of the industrial sector must be taken into account.

As can therefore be observed, the Kaldorian explanation for the differences in economic growth is demand-driven, cumulative and related to sectoral specificities. In contrast to the neoclassical and endogenous growth theories, this approach provides a sectoral interpretation of differences in national growth rates, taking into account not only the supply-side but also the demand-side of a growing process. Thereby, it is more appropriate to the analysis in this work.

1.4 Moving labour towards modern sectors: a short-cut for growth

Since Lewis (1954) published his paper on the importance of inter-sectoral transfer of labour to increase productivity, the possibility of achieving faster growth rates in a short time through structural changes became an important issue in economic theory. According to the author, by assuming an unlimited supply of labour, workers can be transferred from traditional sectors to modern sectors, where productivity is higher, and it increases overall productivity[11]. For Lewis, however, the existence of an unlimited supply of labour is not restricted to underdeveloped economies where most of population works in the agricultural sector. He argues that underutilisation of labour applies for all services in which wages are lower than marginal productivity, such as domestic services, and for those that marginal productivity is negligible, such as “the workers on the docks, the young man who rush forward asking to carry your bag as you appear, the jobbing gardener, and the like”. Essentially, in his approach, the supply of labour is “unlimited” so long as it exceeds the demand at a given price. Therefore, Lewis argues that labour is not a real bottleneck for expansion in the vast majority of countries[12]. Hence promoting structural changes is an important source of productivity growth for many economies.

Although Lewis’s paper was originally published six decades ago, this issue is still addressed by many authors nowadays. McMillan and Rodrick (2011) distinguish this process of increasing productivity by promoting structural changes from the process of productivity growth within a sector. According to them, productivity can growth within economic sectors through capital accumulation, technological change or reduction of misallocation, or, alternatively, labour, can move from low-productivity sectors to high-productivity sectors increasing the productivity of the economy as a whole.

The authors contrasted the successful case of Asia, where productivity grew around 4% per year between 1950 and 2005, to the cases of Latin America and Africa, where productivity growth was around 1% per year. Although the *within* component of productivity growth has played an important role in all cases (it explained around 2% in Africa and Latin America, and more than 3% in Asia), the *structural change*

[11]Denison (1967) incorporates inter-sectoral movements of labour into neoclassical models. He shows that it reduces significantly the Solow residual.

[12]Cornwall (1977) has extended Lewis’ model to advanced economies. The author argues that once demand for labour in high-productivity sectors is increasing faster than the rest of the economy, this sector will face a perfectly labour supply. Thereby, labour is not a constraint for growth even in developing economies.

component has contributed positively only for Asia's productivity growth. In Latin America and Africa, structural change contribution was negative, reducing the positive impact of the *within* component. By splitting the result for Latin America in sub-periods, McMillan and Rodrik verified that both components were equally important in increasing productivity between 1950 and 1970, each one contributing by around 2% per year. Between 1990 and 2005, although the *within* component contributed by the same amount of the former period, the *structural change* component contributed negatively. Consequently, productivity grew only by around 1.5% per year on Latin America.

Following McMillan and Rodrik's (2011) approach, total productivity growth is split in these two components to analyse the contribution of each component and each sector. Labour productivity growth rate can be expressed as:

$$\frac{\Delta Q}{Q_{t=0}} = \underbrace{\sum_{i=1}^{K} \Delta Q \frac{\left(\frac{N_i}{N}\right)_{t=0} + \left(\frac{N_i}{N}\right)_{t=1}}{2Q_{t=0}}}_{(i)} + \underbrace{\sum_{i=1}^{K} \Delta \left(\frac{N_i}{N}\right) \frac{Q_{i,t=0} + Q_{i,t=1}}{2Q_{t=0}}}_{(ii)} \tag{1.1}$$

where Q and Q_i are the labour productivity of the economy and of the sector i, and $\left(\frac{N_i}{N}\right)$ is the share of labour of sector i. The term on the left, (i), presents the contribution of changes in productivity within a sector to the productivity of the economy as a whole. The term on the right, (ii) presents the direct contribution of structural change for the growth of productivity.

Using the Groningen Growth Development Centre (GGDC) database for sectors (Timmer *et al.*, 2014), this analytical tool was employed to split countries' productivity growth into these two components from 1995 to 2008. Table 1.2 presents these results for the three largest developing countries where data is available.

This decomposition shows that structural changes are relatively important to explain productivity growth of the economy only in the Brazilian case, but in terms of total contribution, this component is very limited for all countries. The direct impact of structural change explained around 60% of Brazilian total productivity growth from 1995 to 2008. However, it contributed only by 0.46 p.p. to overall productivity growth. For China and especially for South Korea, the *structural change* component is relatively irrelevant. This component explains 1.50 p.p. of the Chinese total productivity growth per year, whilst the *within* component explains 12.66 p.p. In the case of South Korea, the *structural change* component has a virtually null impact both in relative and absolute terms.

Table 1.2: Sectoral decomposition of overall productivity growth into *within* and *structural change* components, % annual growth (1995-2010)

	Brazil		China		South Korea	
	Within	Str.ch.	Within	Str.ch.	Within	Str.ch.
Total	0.33%	0.46%	12.66%	1.50%	2.96%	0.03%
Agriculture	0.31%	-0.19%	1.25%	-0.60%	0.23%	-0.21%
Mining	0.09%	-0.03%	1.10%	-0.33%	0.01%	-0.02%
Manufacturing	0.17%	0.01%	3.94%	0.97%	2.23%	-0.92%
Utilities	0.09%	-0.05%	0.47%	0.08%	0.14%	0.01%
Construction	-0.08%	0.09%	0.69%	0.22%	0.08%	-0.16%
Trade, restaurants and hotels	0.07%	0.09%	1.34%	0.43%	0.42%	-0.10%
Transport, storage and comm.	-0.20%	0.13%	1.15%	0.22%	0.35%	0.12%
Financial and business services	0.01%	0.21%	1.04%	0.18%	-0.20%	0.44%
Government services	-0.10%	0.16%	1.35%	0.19%	0.00%	0.00%
Social and personal services	-0.03%	0.06%	0.32%	0.15%	-0.31%	0.87%

Within: contribution of changes in productivity within a sector to the productivity of the economy; Str.ch.: contribution of structural change for the growth of productivity. *Total* is calculated as the summation of sectoral contributions for each component (within and structural change). The summation of the components gives the annual productivity growth in the period.
Author's elaboration based on GGDC.

Some sectors are especially relevant to explain productivity growth in these countries. The importance of agriculture is ambiguous once it has contributed positively through within effects, but negatively due to structural changes. Because this sector presents the lowest level of productivity and the share of this sector in total employment reduced in all countries, the second component was expected to be negative. The explanation for the *within* effect in this sector is more complex and controversial. This effect tends to be positive in less developed economies because this sector is composed of traditional activities, such as subsistence, and modern activities. The migration of labour from traditional agriculture to other sectors reduces the relative importance of subsistence activities, and, consequently, the share of modern agriculture increases and the productivity of the sector itself increases. Thereby, the *within* component in agriculture is explained by intra-sectoral structural changes[13].

Manufacturing, on the other hand, presented positive contribution in both components for China and Brazil, and negative contribution in the *structural change* component in Korea. In Brazil and China, the share of employment in this sector has increased, and, because the sector has one of the highest productivities[14], overall pro-

[13]This analysis, however, goes beyond the scope of this work.

[14]Manufacturing does not have the highest productivity among all sectors because it is usually higher in mining and in utilities. However, because the share of employment of these sectors is almost zero (it is less than 2% in China and less than 1% in Brazil and Korea), manufacturing is the sector with the highest potential to promote productivity growth through this mechanism.

ductivity has increased. This fact explains why in China, where the share of this sector in employment grew from 15.4% to 18.7%, the *structural change* component contributed by 0.97 p.p. to overall productivity growth. In Korea, however, the share of employment in this sector decreased by 6.0 p.p., and thus manufacturing contributed negatively by 0.92 p.p. to overall productivity growth due to the *structural change* effect.

Nevertheless, the contribution of manufacturing goes beyond the *structural change* effect. In all cases, the increase of productivity within this sector is among the most important explanation for overall productivity growth between 1995 and 2010. Productivity has grown significantly in the manufacturing sector and, because the share of this sector in the total employment is very significant, its impact on overall productivity was very important. Manufacturing contributed in absolute terms for China and Korea by 3.94 p.p. and 2.93 p.p., respectively. In relative terms, it contributed significantly for all three cases. This component explains around 20% of Brazilian overall productivity growth, as well as 28% of Chinese and 75% of Korean increase in productivity.

The understanding of productivity growth within sectors, with special regards to manufacturing sector, is the focus of this work. The basic explanations for this are the increase in capital-labour ratio and technological changes (even though these two components cannot be dissociated), as will be discussed later. However, as presented in the second section, before starting to discuss these aspects, it is important to consider that intra-sectoral structural changes can also explain why productivity has grown within sectors.

The same analytical tool can be used to split the sectoral productivity growth into the impact of productivity growth within individual industries and the impact of inter-industrial structural changes[15], such as the impact of moving from a low- to a high-tech sector inside the manufacturing sector. As discussed in the second section, it is not only structural changes to industry that are relevant to explain growth, but also intra-sectoral structural changes, once individual industries inside manufacturing present different characteristics and thus different potentials to boost economic growth. Table 1.3 presents the results of the decomposition of productivity growth within manufacturing for the same countries analysed before[16].

[15]Inter-industrial structural changes refer to the movements of labour from individual industries inside a sector to other industries, such as movements from the textile industry to the metals industry.

[16]The database used in this estimation is different to the one used before. Hence, total manufacturing productivity growth may diverge.

Table 1.3: Industrial decomposition of manufacturing productivity growth into *within* and *structural change* components, % annual growth (1995-2007)

	Brazil (1996-2007)		China (1995-2007)		South Korea (1995-2006)	
	Within	Str.ch.	Within	Str.ch.	Within	Str.ch.
Manufacturing (total)*	-1.48%	0.02%	14.1%	-0.31%	2.10%	0.27%
Food, Beverages and Tobacco	-0.27%	0.07%	2.04%	-0.03%	0.19%	-0.06%
Textiles and footwear	-0.14%	-0.03%	1.32%	0.35%	0.35%	-0.49%
Wood and Cork	-0.01%	-0.01%	0.15%	0.05%	0.01%	-0.03%
Pulp, Paper and Publishing	-0.03%	-0.17%	0.61%	0.02%	0.14%	0.01%
Coke and Refined Petroleum	0.39%	0.00%	0.40%	-0.02%	0.08%	-0.08%
Chemicals	-0.46%	-0.14%	1.92%	-0.19%	0.05%	-0.09%
Rubber and Plastics	-0.14%	0.01%	0.42%	0.11%	0.02%	0.21%
Other Non-Metallic Mineral	-0.04%	-0.01%	1.30%	-0.60%	0.15%	-0.15%
Basic and Fabricated Metals	-0.63%	0.10%	2.01%	0.02%	0.00%	0.41%
Machinery and Electrical Eq.	-0.15%	0.08%	2.23%	0.01%	0.42%	0.19%
Transport Equipment	0.01%	0.11%	1.33%	-0.05%	0.62%	0.38%
Manufacturing, Nec.	-0.02%	-0.01%	0.36%	0.04%	0.08%	-0.04%

Within: contribution of changes in productivity within a sector to the productivity of the economy; Str.ch.: contribution of structural change for the growth of productivity. *Manufacturing (Total)* is calculated as the summation of sectoral contributions for each component (within and structural change). The summation of the components for Manufacturing (Total) gives the annual productivity growth in the period.
Author's elaboration based on INDSTAT-UNIDO and WIOD.

From this table it is clear that the *within* effect is the most important to explain why productivity grew in Korea and China, and why it decreased in Brazil. The impact of moving from industries with low productivity towards industries with high productivity has a limited contribution for manufacturing productivity growth, as presented by the *structural change* component. In the case of China and Korea, although manufacturing productivity has grown at high rates, it was only due to the effects of productivity growth within industries, once the *structural change* effect contributed negatively for China and its effects on Korean productivity was virtually zero. In the Brazilian case, on the other hand, manufacturing productivity decreased. However, it was exclusively due to the effects of productivity growth within individual industries, once the impact of inter-industrial structural changes was very limited. Thereby, these results show that productivity growth within individual industries is the main explanation for productivity growth in manufacturing, rather than inter-industrial movements of labour.

According to Rodrik (2013a), these *structural change* and *within* components of productivity growth can be interpreted, respectively, as the results of "structural transformations" and improvements in the "fundamentals". He argues that the former effect is a consequence of moving towards modern sectors, based on Lewis's (1954) approach, and the latter is obtained by accumulating skills and broad institutional capabilities. In this vein, it would be reasonable to conclude that the main explanation for Chinese and Korean productivity growth is improvements in these fundamentals, because the *within* component is the most important component of productivity growth.

Nevertheless, although Kaldor (1966) argued that the direct impact of the *structural change* component is important for less "mature" economies, the author went further than this static analysis, where structural changes only promotes growth through the transfers of labour towards high-productivity sectors. In his view, the growth of productivity through the within component is also explained by structural changes toward modern sectors (in his analysis, manufacturing). According to Verdoorn's law, the faster output growth in manufacturing is, the faster labour productivity will grow due to the existence of static and dynamic increasing returns to scale. Consequently, an explanation for the *within* component of manufacturing productivity growth relies on promoting structural changes towards this sector.

The relationship between structural changes and faster growth of productivity within sectors does not stop here. Many authors, based on different approaches (including Rodrik himself), argue for different potential among sectors to promote catching up in productivity. While in some sectors catching up to frontier technologies is a difficult process, in others, it happens faster, which makes it easy to increase productivity within sectors. Thereby, especially regarding developing economies, the *within* component of productivity growth can be also explained by specialisation in these sectors where technological catching-up is an easier process.

These different approaches for the relation between the sectoral productivity growth and structural changes bring some features to the debate that go further than the explanation given by the fundamentals. These sectoral approaches for the *within* component of productivity, with special regards to manufacturing, will be the object of study in the next sections.

1.5 Technological diffusion and catch-up: sectoral approaches

Based on different approaches, many authors have addressed the fact that countries on a lower technological level have the possibility of growing faster by imitating countries on the innovation frontier. Both in theoretical and empirical investigations, the notion that the higher the technological gap is, the higher the opportunity for growth has proved to be an important explanation for the differential in productivity growth within sectors.

The idea that technological gap is a relevant explanation for growth in the *conditional convergence* approach has been developed by Barro and Sala-i-Martin (1997). Combining the excludability of technology, which is the basis of endogenous growth models, with the notion of imitation, they argue that technological gap is relevant to explain convergence among countries. In this model, the relatively low costs of imitation compared to the costs of discovering new technologies enable developing economies to grow faster than the advanced ones. In the long run, growth depends on the rate of discovery in advanced economies. However, because imitation is typically cheaper than innovation, most countries prefer to copy rather than invent. Consequently, the relatively low cost of imitation implies convergence, as followers grow relatively faster and tend to catch up to the leaders.

Although Barro and Sala-i-Martin's approach is not sector-specific, it enables one of the conditions of convergence to be analysed sectorally. In some specific sectors, such as manufacturing, productivity tends to rise rapidly towards the technological frontier, characterising what Rodrik (2013b) has called "unconditional convergence", in contrast to the conditional convergence that characterises the rest of the economy. According to Rodrik, there are some sectors that can be considered as "escalator activities", once specialisation in these sectors enables countries below the technological frontier to grow faster.

Neo-Schumpeterian authors also address the importance of technological gap to the process of catching-up, even though they emphasise that it is not an automatic process. According to Fagerberg (1994) and Fagerberg and Verspagen (2002), one of the basic assumptions of neoclassical models is that technology is a public good, and, thus, technological gap cannot explain countries' productivity differences. However, rather than a global public good, it is clear that there are large technological differences (or gaps) between countries, and that engaging in technological catch-up (narrowing the technology gap) is perhaps a promising avenue that poor countries can follow for achieving long-term growth. These authors argue that technology (or know-how) is not an international commodity, such as presented by the neoclassicals, because it is not accessible for everybody free of charge. Despite having some characteristics of a public good, technology is embodied in organisational structures. Therefore, although it is possible for countries facing a technological gap to promote a faster growth of productivity by imitating, closing technological gaps is not an automatic but rather a challenging process. Technological catch-up depends on continually transforming technological, economic and institutional structures. Therefore, country-specific factors, such as national systems of innovation, play a crucial role in the process of technological catch-up (Fagerberg, 1994).

In the same vein, Malerba (2002) highlights the importance of sectoral systems of innovation and production. He argues that sectoral systems have a specific knowledge base, technologies, inputs and demand. Thus, focusing on these systems is essential to understanding the learning, innovation and production processes, as well as the transformation of sectors and the factors that determine countries' differential performance in a sector. Therefore, the importance of sectoral technological infrastructure must to be taken into account to understand catching-up processes.

Cornwall and Cornwall (2002) stress that, in the literature on catching-up, the prime determinant of growth is the size of the technology gap, with the most backward economies growing faster, leading to convergence. When it is possible to borrow technology from advanced economies, a backwardness is an advantage, once there is a growth bonus of late industrialisation. According to them, the magnitude of investment cannot show the quality of new capital, and it is particularly interesting for the "catching-up" idea, as investment embodies the most advanced technologies. Hence, for two economies with equal investment to GDP ratio, the more backward of the two will have the faster productivity growth.

However, the existence of technological gap is not sufficient to ensure catching-up. The size of catch-up growth bonus, besides depending on the ability to absorb new technologies, such as stressed by Fagerberg (1994), depends on a very important component of demand: the investment. According to Cornwall and Cornwall, the higher a country's investment rate is, the greater its share of capital that embodies the latest technological advances. Therefore, technological gap growth bonus is not only constrained by technological infrastructure supply, but it is also demand driven, once investment is ultimately determined by demand growth.

Many studies have addressed this issue empirically with the aim of identifying those sectors with the highest potential to promote catching-up. Bernard and Jones (1996) is one of the most cited papers in this topic, somewhat because they found a controversial result. By analysing the role of sectors in aggregate convergence for OECD countries, they found that manufacturing shows little evidence of productivity convergence, whilst other sectors, especially services, are driving the aggregate convergence. Although the β and σ convergence[17] coefficients found by the author for manufacturing is greater in absolute terms than the one found in services, indicating that convergence in the former sector is higher, the standard deviation in manufacturing is greater as well, and only services have coefficients statistically significant different from zero at 5% significance level. It was Sorensen (2001), however, who presented the main critique of this study. The author has shown that the result obtained by Bernard and Jones is not robust to the choice of base year. Sorensen estimated the convergence using different base-years and found that aggregate PPPs are not suitable conversion factors for manufacturing, because it presents strong (and statistically significant) convergence if the base years are 1985, 1990 or 1993. Thereby, the results obtained by Bernard and Jones should not be considered conclusive. More recently, Le Gallo and Dall'erba (2008) used spatial lags as controls to estimate convergence among sectors and regions in Europe. The authors found that labour productivity converges to the same productivity level in manufacturing, in market services and at the aggregate level, whilst in agriculture, construction and non-market services, productivity in peripheral regions and core regions converges to different levels.

Besides these sectoral analysis, some authors have focused on convergence at the individual industry level, such as Dollar and Wolff (1988, 1993), Carree *et al.* (2000) and Van Biesenbroeck (2009). Dollar and Wolff (1988), for example, analysed inter-sectoral convergence for 13 industrialised economies and found positive results in virtually every manufacturing industry, even though convergence was found to be stronger for heavy and high technological industries, such as chemical, machinery and transport equipment, than for low-tech activities. Moreover, they found that convergence is stronger for all manufacturing than at an individual industry level. Carree *et al.* (2000) found large inter-industry differences in the extent of divergence. In contrast to Dollar and Wolff's findings, they show that industries with a high level of productivity have a low rate of convergence, which is in line with high knowledge or capital barriers preventing quick catch-up. Sorensen and Schjerning (2003), however, have argued that these studies provide misleading results because they use aggregate PPP conversion factors to measure sectoral productivity, and these results are sensitive to the base year. They show that manufacturing industries do not present convergence in early base years, whereas they do for later base years. Nevertheless, in contrast to previ-

[17] The β convergence indicates the tendency of countries with relatively high initial levels of output per worker to grow relatively slowly, and the σ convergence indicates the reduction in cross-sectional variance of output per worker.

ous studies, Van Biesenbroeck (2009) estimated convergence for a group of 14 OECD countries from 1970 to 1999 using sector-specific PPP estimations. The author constructed these sectoral conversion factors and found significant robust β convergence for total manufacturing independent of the base year (1985 and 1996), as well as for most individual industries[18].

Taking advantage of having a large dataset, Rodrik (2013b) analysed the β convergence for manufacturing industries among 118 countries in different stages of development. By combining the UNIDO-INDSTAT database, which presents data for manufacturing individual industries, with the Penn World Table, which has data for other sectors, the author found that productivity in manufacturing industries exhibits strong unconditional convergence, while non-manufacturing activities do not. He argues that, in contrast to the overall economy, where convergence is conditional to geography, policies, institutions and other country-specific circumstances, it occurs unconditionally in the modern parts of the economy. According to Rodrik, in contrast to traditional agriculture and many non-tradable services, modern industries produce tradable goods and they can easily be integrated into global production networks, which facilitates technology transfer and absorption.

Even though results are inconclusive at the individual industry level, these studies show that it is important to highlight the role of promoting sectors with higher convergence characteristics, such as manufacturing, to boost aggregate productivity growth. The process of structural change to these sectors is a relevant source of productivity growth for developing economies not only because they present higher levels of productivity than traditional sectors, such as discussed in Section 3, but mainly because productivity within these sectors rise faster than in others due to their intrinsic characteristics.

1.6 Scale economies in a sector-specific demand-driven approach

One of the most important explanations for the productivity growth within sectors is the existence of scale economies (or increasing returns to scale). This concept is definitely not a cutting-edge idea in economic theory. In 1776, using a pin factory as an example, Adam Smith suggested that inventions are stimulated by internal division

[18]The only exceptions are Food, beverages and tobacco and Machinery and equipment using base year 1985 and Mining and quarrying, Textiles, wearing apparel, leather and Transport equipment for both base years (1985 and 1996).

of labour, which, in turn, depends upon the market extension. Many authors have extended this concept for beyond firms' limits. Alfred Marshall, for example, has distinguished internal from external scale economies. Rather than remaining internal to individual firms, scale economies are found at the regional level due to *economies of localisation*. Based on Smith's approach, Young (1928) advocated that division of labour is constrained by the extent of markets, but the main source of market extension is the division of labour itself. According to him, an increase in the supply of commodities enlarges markets *when demand is elastic*. Nevertheless, this process cannot be seen at the industrial level, because an increase in the supply of a commodity increases demand for other commodities. Consequently, the demand generated by an increase in supply does not take place in the same industry, but in the overall economy, and thus the forces of economic progress are endogenous due to the existence of increasing returns at the macroeconomic level.

Young's approach for increasing returns is at the root of Kaldor's (1966) explanation for productivity growth within manufacturing. The author stressed two main points regarding Young's view. Firstly, he argued that instead of a static relation between increase in demand and increase in productivity, scale economies must be seen as a dynamic process. The main sources of technological progress are not related to the size of firms and markets, but to the growth rate of these markets. This process, which is called *dynamic increasing returns to scale*, is related to Arrow's (1962) notion of learning by doing[19], and it implies that a faster productivity growth is strictly associated with a faster output growth, enhancing a process of cumulative causation[20].

The second point stressed by him is that increasing returns to scale are intrinsic to processing or transformation activities, and thus it is a sector-specific factor. An empirical relationship between the growth of manufacturing output and the growth of productivity, known as Verdoorn's law[21], is presented by Kaldor to argue that dynamic increasing returns to scale is not a generalised process, but restricted to processing activities. The author, however, went further and stablished a causal relationship to Verdoorn's law in which the growth of manufacturing output is the determinant of

[19]McCombie (2002) shows how dynamic increasing returns to scale can be derived from Arrow's notion of learning by doing.

[20]Myrdal (1957) presents a similar approach that he called the "principle of circular cumulative causation", which was developed together with Kaldor. The authors criticise the notion of stable equilibrium, arguing that there is no tendency for self-stabilisation. According to Myrdal, changes in institution may lead to further changes in institutions and, because this circular causation tends to become cumulative, changes may "gather speed at an accelerating rate". Thereby, cumulative causation is seen as a process of acceleration of countries' growth rates (rather than only a process of increasing divergence in income levels).

[21]In recognition of Verdoorn's (1949) investigations into that.

productivity growth. According to him, the alternative causality, in which productivity induces a faster growth of demand via cost and price reduction, is flawed because it does not give an explanation for productivity growth differential among countries. The remaining explanation has to be given by autonomous progress in science and technology, but how does this explanation account for verified large sectoral productivity growth rates differential?

Furthermore, an important distinction has to be made from the Kaldorian approach for increasing returns to the one presented by the new growth theorists. Although in both cases productivity growth is determined by output growth, in the former view the ultimate determinant of output is demand. Hence, despite being a phenomenon induced by the supply-side, technological change is demand-driven. In the new growth theory approach, on the other hand, output is ultimately determined by factors of production, which are exogenously given[22]. Hence, in these models, despite being endogenous to output due to the existence of increasing returns to scale, technological changes are supply-constrained.

Kaldor (1972) argues that different from "competitive" markets, such as those for most primary products, manufactures face an "imperfect" competition where producers adjust stocks and production, instead of prices, in response to changes in sales. An increase in demand stimulates output growth, which, in turn, induces investment. Consequently, capital accumulation is endogenous to demand rather than to savings. In this sense, besides being sector-specific due to the characteristics of manufacturing production process increasing returns to scale is demand-driven due to characteristics of manufacturing market structure.

Since Verdoorn (1949) published his paper on the relation between manufacturing output growth and productivity growth, a large number of studies addressed this issue through different perspectives with very controversial results[23]. These different results were found because studies vary in terms of the econometric technique employed, the unit of analysis (cross-country, cross-region, cross-industry or single countries) and due to different methods employed to control productivity growth for capital deepening, such as estimating multifactor productivity rather than labour productivity. Moreover,

[22]Dutt (2006) argues that, in these models, economy is always in full employment and thus all savings are invested. The market mechanisms solve the problems of unemployment and aggregate demand does not deviate from aggregate supply in the long run. Hence, investment, in the long run, is not determined by aggregate demand, but exclusively by savings.

[23]McCombie *et al.* (2002) presented a survey on many of these studies, focusing on the results and techniques employed.

another important difference is the approach these studies are based on. Some of them address this law from a demand-side perspective, based on the Kaldorian approach, and others from a supply-side perspective.

Among these various studies Angeriz *et al.* (2008) is especially interesting because it presents a technique to estimate the supply and demand versions of Verdoorn's law separately. Based on the idea that in the supply approach inputs are exogenous and in the demand approach output is exogenous, the authors estimate these two versions of Verdoorn's law. They conclude that manufacturing presents a significant degree of dynamic increasing returns if demand is considered as exogenous, such as assumed by Kaldor, and it is not significant when inputs are considered as exogenous, such as assumed by the new growth theory, suggesting constant returns to scale. Angeriz *et al.* (2009) expand their later study to evaluate whether these results also hold for more disaggregated industrial data, and concluded that all industries are subject to increasing returns. However, similar to what has been found in early studies, such as McCombie (1985), there is a significant variation in the degree of increasing returns among sectors: the lowest coefficient was found in Textiles and the largest in Electronics.

These results suggest that once it is assumed that output is induced by demand through capital accumulation, the existence of dynamic increasing returns to scale can be an important explanation for productivity growth within sectors. Furthermore, it suggests that it is a phenomenon intrinsic to manufacturing activities and it is especially relevant in some industries, such as found by McCombie (1985) and, more recently, by Angeriz *et al.* (2009).

Araujo (2013) took this concept of increasing returns varying across sectors to understand how a cumulative process takes place in a Pasinettian framework (Pasinetti, 1981; 1993). In Pasinetti's Structural Economic Dynamics (SED), sectors grow at different rates because income elasticities of demand are different. His approach, however, cannot take into account cumulative causation because it considers sectoral technological progress as exogenous. By considering technological progress induced by output rather than exogenous, Araujo explains the Kaldorian process of cumulative causation in a multi-sectoral framework based on Verdoorn's law and the SED approach. A faster growth of output induces productivity growth according to sectoral degree of increasing returns, which increases income. A faster growth of income, in turn, induces output according to sectoral income elasticities of demand, and thus it perpetuates a process of cumulative causation. The higher the specialization in sectors with high degree of increasing returns and high income elasticities of demand is, the greater countries' growth rates are.

1.7 Export-led and balance-of-payments constrained growth models

The demand-driven approach for dynamic increasing returns is at the root of the Export-Led Cumulative Causation (ELCC) model developed by Kaldor (1970) and formalised by Dixon and Thirlwall (1975). According to the model, any exogenous shock in the autonomous demand will set up multiplier and accelerator effects[24] in local production triggering a process of cumulative causation due to the existence of increasing returns to scale. From the point of view of any particular region, exports are the major component of autonomous demand. Hence, a faster growth of exports will stimulate output growth, and, due to Verdoorn's law, productivity will grow faster. In the ELCC model, competitiveness in external markets is essentially a function of "efficiency wages", which is determined by wages and productivity. A relatively faster growth of productivity promotes movements of efficiency wages in favour of the region, and thus region's share in world market increases. Consequently, a faster productivity growth stimulates exports, which, in turn, stimulates output and productivity, characterising a circular and cumulative process.

The ELCC model is very elusive in terms of showing how a cumulative process takes place in an open economy. However, it is important to note that it has some drawbacks. Firstly, although Kaldor has stressed the importance of manufacturing as the sector where dynamic increasing returns occur and the sector where growth in demand reflects in output growth, the model does not consider *explicitly* a multisectoral approach. Although it is implicitly considered because this cumulative process only takes place in industrialised economies, by considering different sectors explicitly (such as Araujo (2013) presented for a closed economy[25]) is relevant to explain how structural changes towards sectors with the highest increasing returns stimulates a process of cumulative causation.

Another important issue is the fact that the mechanism behind cumulative causation in this model is price-competitiveness. Nevertheless, there is a large body of

[24] The author refers to Hicks's super-multiplier to account for the effects on induced investment. This effect goes beyond the income-effect given by the traditional Keynesian multiplier.

[25] As we will see later, Araujo considers his model in the context of an open economy. However, due to his assumptions, the model loses virtually all its cumulative causation characteristic.

literature arguing that non-price competitiveness is the most important determinant of long-term growth of exports (Kaldor, 1978; Fagerberg, 1988; McCombie and Thirlwall, 1994). Technological factors, quality of products, reliability and speed of delivery are considered as more important by far to explain export growth in the long run rather than costs. Kaldor (1978), for example, found that the countries that had the greatest increase in their market share were those that experienced the greatest growth rates in prices, in contrast to what is predicted by the ELCC model. The "Kaldor Paradox", as it is known, is explained because the increase in prices is not the cause, but the consequence of changes in non-price competitiveness, such as improvements in the quality of goods.

One of the main critiques of this model, however, is based on another strong assumption made by Kaldor (1970). According to the model, both the level and the growth of imports will adjust to accommodate the growth of exports. This assumption implies that a faster growth of exports will increase imports at the rate of exports through multiplier effects, and hence countries' capacity to import is not a constraint. However, it ignores the fact that income elasticities of demand for imports might be different from the unity, and thus a faster growth of output might increase imports at a faster rate than exports, leading countries to a balance-of-payments crisis.

By relaxing this strong assumption, important changes in this model have to be made, once output growth will not be determined only by export growth, but by the growth rate that avoids this balance-of-payments crisis. Thirlwall (1979) formalised this approach considering that exports and imports have to grow at the same rate to avoid balance-of-payments constraints. Based on the assumption that, measured in the same currency, prices cannot grow at different rates in the long run, the growth rate of a given country is determined by the growth rate of world income multiplied by the income elasticities ratio[26] – both exogenously given[27].

The balance-of-payment-constrained growth (BPCG) model, also known as Thirlwall's law, despite its simplicity, provides an interesting explanation for countries'

[26]Elasticity of demand for imports in relation to the country income divided by the elasticity of demand for exports in relation to world income. As discussed in McCombie and Thirlwall (1994), these elasticities reflects non-price competitiveness.

[27]Krugman (1989) provides a very similar model, called by him as 45-degree rule, but assuming these elasticities endogenous to productivity. A similar approach was adopted by Palley (2003), but based on a Kaldorian view. The author stressed that productivity, determined by Verdoorn's law, affects the income elasticities of demand, and the elasticities respond passively to changes in the natural rate of growth. A brief review of Krugman and Palley's approach, as well as a critique can be found in McCombie (2011).

growth rate divergence. Firstly, a large number of studies tested this law empirically and most of them have confirmed its importance in explaining countries' growth rates[28]. Secondly, because of its simplicity, this model enables an incredible number of extensions to explain why countries' growth rates diverge. Thirlwall and Hussain (1982), for example, extended the model to allow for capital inflows and found it to be very relevant to explain developing countries' long-term growth rates.

Some specific extensions of this model are especially interesting for the analysis of this work. Araujo and Lima (2007) extended Thirlwall's model to a multisectoral framework to understand how sectoral changes in the composition of imports and exports explains countries' growth rates. The multisectoral version of Thirlwall's law, as the authors named it, asserts that sectors present different income elasticities of demand for imports and exports and countries' BPCG rates are given by the weighted income elasticities ratio. Although sectoral elasticities are exogenous, promoting structural changes towards sectors with high elasticities increases countries growth rates in the long run. This approach is especially interesting because it brings back the debate on the importance of structural change, which cannot be seen explicitly in Thirlwall's original model.

Gouvea and Lima (2010; 2013), Romero *et al.* (2011) and Tharnpanish and McCombie (2013) tested empirically this multisectoral version from different econometric approaches and found that manufacturing products, with special regards to high-tech and capital goods products, present higher income elasticities than primary products. Moreover, Gouvea and Lima (2010) argued that, unlike South American countries, Asian countries have managed to change the composition of their exports and imports in a way that increased the weighted income elasticities. Hence, the difference between growth rates in Asian and Latin American economies can rely on the composition of exports and imports.

Both the original and the multisectoral Thirlwall's law made important contributions for growth theory, but they do not incorporate an important aspect of the Kaldorian approach exhaustively discussed before: the existence of increasing returns to scale in manufacturing and its importance for a cumulative causation process. Araujo (2013) attempted to reconcile the multisectoral version of Thirlwall's law with his Pasinettian approach for cumulative causation. Nevertheless, the author considers that dynamic increasing returns to scale affects only price competitiveness, and, because the main determinant of international competitiveness is non-price factors, the mechan-

[28] Thirlwall (2011) presents a systematisation of many of these studies.

ism from which cumulative causation is presented in Araujo's model plays very limited role in the multisectoral version of Thirlwall's law. In Araujo's model, countries' long-term growth rates are virtually determined only by the exogenous weighted income elasticities, whilst endogenous technological change plays a limited role[29].

In order to incorporate cumulative causation in the BPCG models, Setterfield (2011) extends Thirlwall's original model to consider that output growth promotes productivity improvements due to Verdoorn's law, but, rather than reducing prices, it increases the quality of products[30]. Because income elasticities of demand for imports and exports measure non-price competitiveness, there is a clear causal relationship from output growth to these elasticities. The higher output growth rates are (in relation to world output growth), the faster the income elasticities ratio increases. An increase in the elasticity ratio, in turn, affects positively output growth due to Thirlwall's law, and, consequently, a process of cumulative causation through a Kaldorian mechanism takes place. Thereby, Setterfield's approach is capable of explaining cumulative causation even in a BPCG model. However, because it does not consider a multisectoral approach, divergence in countries' growth rates are explained by past growth rates rather than by the sectoral structure of production and trade.

Fiorillo (2001) presents an export-led model with cumulative causation in a multisectoral framework. The author considers a feedback effect from output growth to exports in order to explain the coevolution of structural change and growth. Based on sectoral Verdoorn's law and its effects on income elasticities, Fiorillo shows that a cumulative process takes place because sectoral specialisation determines aggregate growth, while the latter modifies sectoral specialisation. Nevertheless, although constructed based on Thirlwall's law, his model does not take into account an explicit multisectoral BPCG framework[31]. Consequently, Fiorillo's model does not show explicitly to what extent the interaction between different income elasticities of demand and increasing returns to scale among sectors explains growth in open economies.

In this vein, a model that combines different sectoral degrees of increasing returns,

[29] In Araujo (2013), cumulative causation emerges from the fact that countries have different sectoral elasticities of demand according to their income per capita. As countries grow, the demand shifts towards products with higher income elasticities, and it has an impact on the BPCG rate.

[30] Although the BPCG model explains why countries' growth rates are different (and hence why their income levels diverge), Setterfield considers cumulative causation as the process of acceleration of countries' growth rate divergence.

[31] Furthermore, Fiorillo's model is based on the notion that growth in mark-up is the main source of technological change. However, as shown by Kaldor's paradox, countries' market share is positively related to prices, but not due to a reduction in the wage share, such as in this model. In fact, unit labour costs are also positively related to market share, following the same trend of prices.

different sectoral income elasticities of demand for imports and exports, and the notion of cumulative causation, such as presented by Setterfield (2011), is fundamental to understanding the dynamics of countries' growth rates divergence and its origins through a sectoral perspective, such as stressed by Kaldor.

1.8 Concluding remarks

There is clear evidence that countries' long-term economic growth is strictly related to structural changes. The reason for that, on the other hand, is much less clear. An important explanation for overall productivity growth is the impact of transferring labour from sectors with low levels of productivity to high-productivity sectors. However, the scope for increasing productivity through this process showed to be relevant only for countries in the early stages of development. For middle-income countries, such as China and Brazil, the main source of productivity growth relies on productivity growth within sectors.

In contrast with the traditional approach that explains the productivity growth within sectors through fundamentals, some alternative approaches advocate that structural changes are also an important source of sectoral productivity growth. Firstly, because some sectors have higher potential to promote catching-up than others, they can play as "escalator activities". Specialisation in these sectors allows developing countries to grow faster by imitating countries on the technological frontier. Secondly, some sectors present higher degrees of increasing returns than others, and thus by promoting structural changes towards these them is an important source of productivity growth within sectors. Finally, sectors present different income elasticities of demand for imports and exports. For an open economy, promoting exports of sectors with high-income elasticities of exports and reducing imports of sectors with high-income elasticities of imports is essential to avoid balance-of-payments constraints.

For all explanations presented before, manufacturing, with special regards to high-tech industries, is the sector more favourable for promoting faster growth. This sector has the highest potential to promote catching-up, the highest degree of increasing returns and the highest income elasticities of demand for exports and imports. Moreover, because this sector presents all these characteristics, it is expected that specialisation in manufacturing will promote a cumulative process of growth. A faster output growth in manufacturing increases productivity, which, in turn, increases overall growth, reinforcing the initial stimulus.

Kaldor exhaustively stressed a cumulative process in these lines. However, modelling it from a multisectoral perspective is not a simple task and it was not made explicitly by any Kaldorian model for open economies. Some models, such as Setterfield (2011), take into account balance-of-payments constraints and cumulative causation, but not in a multisectoral framework. Others, such as Araujo (2013) and Fiorillo (2001), consider cumulative causation in a multisectoral framework, but not balance-of-payments constraints. A third group, where Araujo and Lima (2007) are included, considers balance-of-payments constraints in a multisectoral framework, but cumulative causation does not emerge from sectoral specialisation.

The following chapters of this thesis will address these issues. The first part of the thesis aims to analyse how specialisation in sectors with high income elasticities of demand for imports and a high degree of dynamic increasing returns can trigger a process of cumulative causation, where countries' growth rates diverge in the long run. The second part analyses some developing economies to contrast different patterns of sectoral specialisation and its consequences for growth in the long term.

Chapter 2

Structural changes in the world demand: impacts of a faster growth of developing countries on natural-resource exporters

2.1 Introduction

The world's structure of production has deeply changed in terms of localisation since the 1990s. Although the worldwide annual growth rate fell from 4.1% between 1960 and 1990 to 2.7% from then on, this change differs significantly when high-income countries are compared to low and middle-income countries. According to the WB-WDI, the annual growth rate in the group of high-income countries fell from 4.1% to 2.1%, while low and middle-income countries experienced an increase in their annual growth rates from 4.5% to 5.0% over the same period. Considering the 2000s alone, the differences are even greater: the annual growth rate in the high income countries dropped to 1.6%, while that among low and middle-income countries rose to 6.0%, as can be seen in Table 2.1:

Thereby, since the 1990s, developing countries growth rates have been increasing whereas developed countries growth rates have been decreasing. Because countries have different demand structures (according to their income level), the faster growth of developing countries has promoted a structural change in world demand as a whole. As the demand for some products were boosted over others, countries exporting such demand growing products tended to be positively affected. One could expect, for example, that an acceleration of the Chinese growth relatively to the US will stimulate

Table 2.1: Annual growth rate per countries' income level (1960-2010)

	High income	Low and middle income	World
1960s	5.3%	5.1%	5.3%
1970s	3.6%	5.3%	3.8%
1980s	3.3%	3.1%	3.2%
1990s	2.7%	3.8%	2.9%
2000s	1.6%	6.0%	2.5%
1960-1990	**4.1%**	**4.5%**	**4.1%**
1990-2010	**2.1%**	**4.9%**	**2.7%**

Source: World Development Indicators, World Bank.

the demand for minerals and food over the demand for electronic appliances. Hence, countries that export minerals and food predominantly are benefited, whilst those exporting electronics might face a smaller impact. In sum, the dynamics of a country exports essentially depends on its sectoral structure together with the difference among trading partners growth rates.

Based on a Kaldorian approach, in which exports' dynamics play a crucial role to understanding the difference in growth rates across countries, this chapter wishes to explain countries' growth rates taking into account that non-homogeneous growth across different groups of countries has been an important issue since the 1990s, such as discussed before. The aim of the chapter is to render these changes in the structure of world demand as endogenous in a BPCG model. As discussed in the first chapter, this model explains countries' growth rates through income elasticities of demand for imports and exports, and thus taking into account different income elasticities according to commercial partners is a possible source of explanation for the impact of these structural changes.

According to the BPCG model, economic growth is constrained by countries' capability to export, and its long-term growth rate is given by the ratio between the growth of exports and the elasticity of imports (Thirlwall, 1979; McCombie and Thirlwall, 1994). Further on, more complex versions of Thirlwall's model have tried to provide more precise interpretations on this phenomenon by analysing countries' growth from various perspectives and by incorporating other factors such as capital inflows and interest payments. Two direct extensions of Thirlwall's model developed in the 2000s are specifically related to the model developed in this chapter. First, based on the theoretical model developed by McCombie (1993), Nell (2003) presents a multilateral BPCG model to explain how trading partners can affect the exports of a country. Moreover, Araujo and Lima (2007) develop a multisectoral version of this model in order to explain how changes in the sectoral structure of exports and imports affect countries' long-term growth rates. However, these models are not able to take account of the impacts of structural changes in the world demand on countries' long-term growth rates.

With the aim of rendering the impacts of (structural) changes in world demand as endogenous, this chapter develops a version of the BPCG model that is both multisectoral and multilateral. This approach is capable of considering the difference among trade partners' growth rates on countries' exports. Being multilateral, the model regards the effect of different growth rates among countries in different stages of development. Moreover, a multisectoral model is needed because, once these partners are growing at different paces, it affects the sectoral structure of the world demand and, consequently, the sectoral structure of countries' exports.

After presenting the model theoretically, it is applied to South American and Asian economies. This empirical analysis enables us to compare the recent growth pattern of two distinct groups of countries: one that is mainly a natural-resource exporter (South America) and the other that exports manufactured goods mostly (Asia). This purpose of this investigation is to discusses whether the impact of these changes in world demand have had structural and permanent effects on countries' growth rates or, alternatively, whether they are only conjectural and not sustainable in the long-run. South American countries' growth in the 2000s was directly related to the growth in the demand for natural resources. The acceleration of the developing countries' growth rates, particularly in Asia, has increased the world demand for food and minerals, which has relaxed the balance-of-payments constraints of natural-resource exporters. As a result, one of the most important restrictions on South American economic growth in the last two decades may have been significantly reduced. From this perspective, the model developed here considers the impact of a faster growth of developing economies on countries' exports to explain why natural resource exporters have been lately achieving higher growth rates. Furthermore, the model is also used to evaluate the sustainability of these higher growth rates in the long run.

This chapter is divided into five sections. After this introduction, Section 2.2 presents the first BPCG model developed by Thirlwall (1979) and some extensions related to this work. The third section discusses why these models are not able to explain completely the impacts of such worldwide structural changes and an extension to BPCG models is presented with the aim of rendering the impact of these changes in world demand as endogenous. In the fourth section, the model is applied to Brazilian data in order to investigate the impact of that structural change on its long-term growth, as well as to other developing economies with the aim of comparing the results. Finally, the last section discusses the importance of the model to explain the differences on countries' growth rates, as well as its limitations.

2.2 Thirlwall's model and some extensions

From a Post-Keynesian perspective, the growth rate of a given region is demand-driven. This point of view, which will be considered along this work, implies that differences of growth between countries are not explained by the supply factors, such as in neoclassical and new growth models, but they are mainly explained by the sources of demand. Essentially, in the case of open economies, the primary autonomous source of demand is external demand. Exports increase the income growth through their multiplier effects on the other sources of demand. Furthermore, as exports are the only component of aggregate demand able to generate foreign currency, they allow the growth of other sources of demand without generating balance-of-payments constraint.

Thirlwall (1979) developed the first balance-of-payments constrained growth (BPCG) model. In his paper, he argues that the differences between countries' growth rates are better explained by the Keynesian approach, which stresses the constraints on demand, than the neoclassical approach, which is based on supply factors (Thirlwall, 1979; McCombie and Thirlwall, 2004). He also argues that in the case of open economies, the balance-of-payments is the dominant constraint on demand growth. Therefore, a country's long-term growth rate (where the balance-of-payments equilibrium must be maintained) is given by its ability to increase the growth of exports and reduce the growth of imports. The Thirlwall's model was constructed as follow:

The balance-of-payments equilibrium on current account can be expressed as:

$$P_{dt}X_t = P_{ft}M_tE_t \tag{2.1}$$

where X and M are the exports and imports, respectively (both in constant prices), P_d is the export prices in domestic currency, P_f is the import prices in foreign currency, E is the exchange rate (measured as domestic currency divided by the foreign currency), and the subscript t is time.

Aiming to work with growth rates instead of absolute values this expression is written in its growth form:

$$p_{dt} + x_t = p_{ft} + m_t + e_t \tag{2.2}$$

where lower-case letters represent rate of changes.

Taking the standard demand theory, imports are expressed as a multiplicative function of the price of imports in domestic prices, the price of import substitutes and the level of domestic income. This expression can be linearised as:

$$m_t = \psi(p_{ft} + e_t) + \theta p_{dt} + \pi y_t \tag{2.3}$$

where ψ is the price-elasticity of imports, θ is the cross-elasticity of imports, π is the income elasticity of imports, and y is the domestic income growth.

Exports can also be expressed as a multiplicative function. Its arguments are the price of demand for exports in foreign prices, the price of goods competitive with exports and the level of world income. A linearised version of this expression is:

$$x_t = \eta(p_{dt} + e_t) + \delta p_{ft} + \varepsilon z_t \tag{2.4}$$

where η is the price-elasticity of exports, δ is the cross-elasticity of exports, ε is the income elasticity of exports, and z is the world income growth.

Substituting equations (2.3) and (2.4) into (2.2), and solving for y_t, the balance-of-payments constrained growth rate can be expressed as follow:

$$y_{Bt} = \frac{p_{dt}(1 + \eta - \theta) - p_{ft}(1 - \delta + \psi) + \varepsilon(z_t)}{\pi} \tag{2.5}$$

Finally, assuming that the own price-elasticities of imports and exports are equal to the cross-elasticities, as well as that the relative prices measured in a common currency do not change in the long-run, the BPCG rate can be expressed as:

$$y_{Bt} = \frac{\varepsilon}{\pi} z_t \tag{2.6}$$

This equation shows that the BPCG rate of a country is given by the ratio of the income elasticities of demand for exports and imports multiplied by the rate of growth of world income. This equation is widely known as Thirlwall's law. In his paper, the author applied this equation to a group of several developed countries. Although his econometric method was subsequently contested (McCombie, 1997), the author's results showed that this law is able to explain a significant amount of the growth in the analysed countries.

After Thirlwall's inaugural article, some new models were developed based on his approach. While Thirlwall's model has been able to explain the differences in growth rates among developed countries, some extensions were made to explain different factors that may affect countries' growth rates. Thirlwall and Hussain (1982), for example, extended the model to apply it to developing countries. According to the authors, "it must be recognized, though, that developing countries are often able to build up ever-growing current account deficits financed by capital inflows". Thus, Thirlwall's equation was modified to allow for capital flows. The modified model was applied to a group of developing countries, and capital flows were shown to be relevant in explaining some of their growth rates, e.g., Brazil, Tunisia, Pakistan and India.

Two direct extensions of Thirlwall's model developed in the 2000s are specifically related to the proposed model that is developed here. First, based on the theoretical model developed by McCombie (1993), Nell (2003) applied the BPCG models to neighbouring regions. Although his model may be criticised, since it considers that a country should have balance-of-payments equilibrium with all trading partners, it provides relevant insights in terms of the importance of considering countries' multilateral relations. The author considered the original model as a specific case where one country has relations with "the rest of the world". Then, he developed a "generalised" version of this model where a country may have multilateral trade relations. He showed that trading partners might affect the exports of a country differently. According to him, "the main finding of the paper is that the policy implications of the 'generalised' BOP growth model present a different perspective compared with the 'specific' BOP model". In Nell's model, the long-term growth rate of a country is explained by the ratio of the weighted average of exports for each trading partner to the weighted average of income elasticities for imports from each trading partner. Although he has propounded the model for two partners, it may be generalised for K partners:

$$y^a_{Bt} = \frac{\sum_{j=1}^{K}(y^j_t \gamma^j_t \varepsilon^j)}{\sum_{j=1}^{K}(\phi^j_t \pi^j)} \tag{2.7}$$

where K is the number of trading partners and the index j is the each partner (country or region), the index a is the home country, γ is the share of exports to each partner as a percentage of total country's exports, and ϕ is the share of imports from each partner as a percentage of total country's imports.

Araujo and Lima (2007) proposed the other recent study related to the model developed in this chapter. The authors extended Thirlwall's original model to explain the importance of changes in the sectoral structure of exports and imports on the long-run growth rate of a country. They used Pasinetti's structural economics dynamic (SED) approach to derive a multisectoral version of Thirlwall's law. In Araujo and Lima's model, the growth rate of a country is directly proportional to the sectoral income elasticities of demand for exports and imports weighted by coefficients that measure the share of each sector in total exports and imports. According to the authors, the main implication of this extension is that "changes in composition of demand or in the structure of production (. . .) also matter for economic growth". The multisectoral version of BPCG model can be expressed as follow[32]:

$$y_{Bt} = \frac{\sum_{i=1}^{N}(\gamma_t^i \varepsilon^i)}{\sum_{i=1}^{N}(\phi_t^i \pi^i)} z_t \tag{2.8}$$

where N is the number of sectors and the index i is each sector, ε and π are the income elasticity of demand for exports and imports of each sector, respectively, γ is the share of exports of each sector, and ϕ is the share of imports of each sector.

2.3 Incorporating world structural changes into BPCG models

Although the models developed by Nell (2003) and Araujo and Lima (2007) are relevant in explaining certain issues related to the differences in countries' growth rates, they have to be extended to evaluate the impacts of non-homogeneous growth across countries on the structure of world imports. These models do not consider the impacts of structural changes in world demand to be endogenous. On the one hand, the multisectoral version of the BPCG model (Araujo and Lima, 2007) assumes that elasticities are only affected by changes in the composition of imports and exports, and thus differences in growth rates between a country's trading partners do not affect growth. On the other hand, the multilateral BPCG model (Nell, 2003) do not consider the effect of non-homogeneous growth in the world economy on the sectoral structure of world demand. The latter model considers the impact of different growth rates across trading partners, but not from a sectoral perspective. However, a relevant consequence of different growth across trading partners is that they affect the sectoral composition of world demand, and thus the sectoral income elasticities of demand. As argued by Pasinetti (1981) and Cornwall (1977), income growth affects demand

[32] Although the multisectoral version of BPCG was developed by Araujo and Lima (2007), this expression is based on Setterfield's (2011) version of their model.

because consumers move through a 'commodity hierarchy' in which different goods have different income elasticities of demand in different levels of income.

Thereby, non-homogeneous growth across trading partners according to their income levels may directly affect a country's growth rate, once it affects the world's import structure (according to their income elasticities for imports) and thus this country's exports. Consequently, a country's export growth rate (and thus the balance-of-payments constrained growth rate) depends on the sectoral structure of exports, as suggested by Araujo and Lima (2007), but it also depends on the difference between the growth rates of its trading partners. Hence, a new model has to be developed and studied in depth to understand the impact of global structural changes in the 2000s on countries' long-term growth rates. The multisectoral Thirlwall's law has to be extended to a model that considers the impact of different growing trajectories across trading partners on countries' exports, and thus on their balance-of-payments constraints.

Thereby, to model structural changes in world demand and their impact on exports as endogenous, the two extensions of Thirlwall's model previously described will be combined in the construction of this new model. Both the multisectoral model (Araujo and Lima, 2007) and multilateral model (Nell, 2003) will be considered together with the aim of investigating the impact of different growth rates of trading partners on countries' sectoral structure of exports and thus on their growth rates. In this new model, the income elasticity of demand for exports is divided into the income elasticities of demand for exports across sectors and trading partners. The export growth is given by the weighted income elasticities multiplied by the growth rate of each trading partner. This division enables the model to distinguish the impacts of the growth rates of different trading partners on a country's BPCG.

Let us start by considering 2 goods and 3 countries:

- Goods: (1) primary, and (2) secondary
- Countries: (a) home country, (d) developed, and (u) underdeveloped

The total imports of the country a can be written as:

$$M_{at} = M_{at}^{1}d + M_{at}^{2}d + M_{at}^{1}u + M_{at}^{2}u = \sum_{j=1}^{2}\sum_{i=1}^{2} M_{at}^{ij} \tag{2.9}$$

where M is the imports of the home country (in the subscript) from its trading partner (in the superscript). The indices i, j and t represent the goods, the trading partners and each period, respectively.

Taking the standard demand theory, the import demand function of the home country is given as follow[33]

$$M_{at}^{ij} = \left(\frac{P_{at}^{i} E_{at}^{j}}{P_{jt}^{i}} \right)^{\psi_a^{ij}} (Y_{at})^{\pi_a^{ij}} \tag{2.10}$$

where P is the price of i in the country in the subscript (a or j), E is the exchange rate between a and j, ψ is the price-elasticity of demand for imports, and π is the income elasticity of demand for imports.

Considering that relative prices measured in domestic currency do not change over time, country a's import growth rate of each good i from each country j can be written as:

$$m_{at}^{ij} = \pi_a^{ij} y_{at} \tag{2.11}$$

where lower cases mean growth rates.

The total import growth is the weighted average of the import growth of each sector i from each country j in the period t:

$$\begin{aligned} m_{at} &= \gamma_{at}^{1d} \pi_a^{1d} y_{at} + \gamma_{at}^{1u} \pi_a^{1u} y_{at} + \gamma_{at}^{2d} \pi_a^{2d} y_{at} + \gamma_{at}^{2u} \pi_a^{2u} y_{at} = \\ &= \sum_{j=1}^{2} \sum_{i=1}^{2} (\gamma_{at}^{ij} \pi_a^{ij} y_{at}) = y_{at} \sum_{j=1}^{2} \sum_{i=1}^{2} (\gamma_{at}^{ij} \pi_a^{ij}) \end{aligned} \tag{2.12}$$

where γ is the share of imports of each sector i and country j in the total imports of a in each period:

$$y_{at}^{ij} = \frac{M_{at}^{ij}}{M_{at}} \tag{2.13}$$

The import growth of the other countries can be obtained by analogy to (2.12):

[33] For simplicity, price-elasticities of substitution between goods is not taken into account. Although it is not negligible, prices do not play any role in Thirlwall's model in the long run, and thus it does not change the results.

$$m_{dt} = \gamma_{dt}^{1a}\pi_d^{1a}y_{dt} + \gamma_{dt}^{1u}\pi_d^{1u}y_{dt} + \gamma_{dt}^{2a}\pi_d^{2a}y_{dt} + \gamma_{dt}^{2u}\pi_d^{2u}y_{dt} \tag{2.14}$$

and

$$m_{ut} = \gamma_{ut}^{1a}\pi_u^{1a}y_{ut} + \gamma_{ut}^{1d}\pi_u^{1d}y_{ut} + \gamma_{ut}^{2a}\pi_u^{2a}y_{ut} + \gamma_{ut}^{2d}\pi_u^{2d}y_{ut} \tag{2.15}$$

Note that imports growth of the countries d and u from the country a are equal to the export growth of a to d and u, respectively. Thus, the export growth of the domestic country can be written as the weighted average of the imports of the d and u from a:

$$x_{at} = \phi_{at}^{1d}\pi_d^{1a}y_{dt} + \phi_{at}^{2d}\pi_d^{2a}y_{dt} + \phi_{at}^{1u}\pi_u^{1a}y_{ut} + \phi_{at}^{2u}\pi_u^{2a}y_{ut} =$$

$$= \sum_{j=1}^{2}\sum_{i=1}^{2}(\phi_{at}^{ij}\pi_{ji}^{ia}y_{jt}) = \sum_{j=1}^{2}\left(y_t^j\sum_{i=1}^{2}(\phi_{at}^{ij}\pi_{ji}^{ia})\right) \tag{2.16}$$

where ϕ is the share of each sector i of each country j in the total exports of a in each period:

$$\phi_{ijt}^a = \frac{X_{jit}^a}{X_t^a} \tag{2.17}$$

Finally, considering that income elasticity of demand for imports from country j to a is equal to income elasticity of demand for exports from country a to j, the 2 goods and 3 countries BPCG rate (Thirlwall's law) for the home country can be written as:

$$y_{B_{at}} = \frac{\sum_{j=1}^{2}\left(y_{jt}\sum_{i=1}^{2}(\phi_{at}^{i}j\varepsilon_a^i)\right)}{sum_{j=1}^{2}\sum_{i=1}^{2}(\gamma_{at}^{ij}\pi_a^{ij})} \tag{2.18}$$

where ε is the income elasticity of demand for exports.

The generalised model for N goods and K trading partners is given by:

$$y_{B_{at}} = \frac{\sum_{j=1}^{K}\left(y_{jt}\sum_{i=1}^{N}(\phi_{at}^{i}j\varepsilon_a^{ij})\right)}{sum_{j=1}^{K}\sum_{i=1}^{N}(\gamma_{at}^{ij}\pi_a^{ij})} \tag{2.19}$$

Furthermore, if we consider the income elasticity of demand for imports (π) of each country to be independent from the country that they come from, which is reasonable as the aim of this chapter is to analyse the impacts of structural changes in world demand on countries' exports, a simplified model is given by:

$$y_{B_{at}} = \frac{\sum_{j=1}^{K}\left(y_{jt}\sum_{i=1}^{N}(\phi_{at}^{i}j\varepsilon_{a}^{ij})\right)}{\sum_{i=1}^{N}(\gamma_{at}^{i}\pi_{a}^{i})} \tag{2.20}$$

Alternatively, by defining σ_{jt} as the growth rate of trading partner j over the world growth rate[34], the model can be rearranged as follow:

$$y_{B_{at}} = \frac{\sum_{j=1}^{K}\sum_{i=1}^{N}(\sigma_{jt}\phi_{at}^{ij}\varepsilon_{a}^{ij})}{\sum_{i=}^{N}(\gamma_{at}^{i}\pi_{a}^{i})} z_t \tag{2.21}$$

Equation (2.21) shows explicitly how the non-homogeneous growth rates among trading partners affect the home country's long-term growth.

Thus, we have that the long-term growth rate (given by the BPCG rate) depends on the country's structure of imports and exports, as suggested by Araujo and Lima's model, but it also depends on the difference in growth rate among trading partners. In their multisectoral model, a country may achieve a higher growth rate by increasing exports of sectors with high income elasticities or by reducing their imports. In the model developed here, a country may also grow faster due to an increase in trading partners' growth rates. This second engine takes place when the partners that are experiencing the faster growth demand relatively more of the goods exported by the home country, resulting in a higher BPCG rate. Therefore, based on the model developed here, it is possible to evaluate whether, during the 2000s, the faster growth of developing countries (relatively to developed countries) had structural and permanent impacts on the growth rate of natural resources exporters.

2.4 Data, econometric method and empirical results

The aim of this section is to estimate the model presented in the last section using developing countries data and to compare the results with those obtained by some empirical application of multisectoral models, such as in Gouvea and Lima (2010). However, before doing so, some initial explanations in terms of methods and data are presented in the following subsection.

[34] $\sigma_{jt} = \frac{y_{jt}}{z_t}$, where z_t is the world growth rate

2.4.1 Data sources and sectoral classification

Once it was assumed that the main source of changes in world demand comes from differences in growth rates among countries with diverse income levels, this section divides the trading partners of each country under consideration into "high income level countries" (HIC) and "low and middle income level countries" (LIC)[35]. Although this division is a generalisation of a more complex process, it makes the model capable of considering the above mentioned structural changes in world demand.

Regarding the sectoral division, two approaches are employed.

Firstly, the Broad Economic Categories (BEC) classification is used to analyse the elasticities according to categories of demand. According to this classification, sectors of the *Standard International Trade Classification (SITC), Rev. 1* are grouped into: large economic classes of commodities, distinguishing foods, industrial supplies, capital equipment, consumer durables and consumer non-durables. As a matter of simplification, the following analysis aggregates these sectors in only three groups: (1) Natural Resources (NR) – commodities, distinguishing foods and industrial suppliers; (2) Consumption Goods (CG) – consumer durables and consumer non-durables goods; and (3) Capital Goods (KG) – capital and transport equipment (including parts and accessories).

Secondly, exports and imports are grouped into Primary Products (PR), Low-tech manufacturing (LT) and High-tech manufacturing (HT). This classification is based on the UNIDO (2013:205) classification for manufacturing activities (LT and HT), and Primary Products encloses agriculture and mining.[36]

The analysis employed in this paper takes the largest economies of South American and South and East Asian countries[37]. The South American countries are Argentina, Brazil, Chile, Colombia, Peru and Venezuela. The South and East Asian countries are Hong Kong, India, Korea, Malaysia, The Philippines, Singapore and Thailand[38]. China and Indonesia were excluded from the analysis because data are not available for the initial years. The source used for exports and imports data is the United

[35] Countries are classified according to World Bank division.

[36] Appendix A presents the classification employed in this analysis.

[37] Because many countries in Central America and Mexico are not predominantly natural-resource exporters, South American countries are considered instead of Latin American countries.

[38] Because the method employed in this work demands strongly balanced panels and some countries do not have data for specific years, some adjustments were made in the database before conducting the estimations: Indian imports in 1982, Peruvian exports and imports in 1981, Thai exports in 1988 and Venezuelan exports in 2007 were obtained by averaging previous and next years (in log).

Nations Commodity Trade Statistics (COMTRADE) database. These data (in *SITC, Rev. 1*) are available for several countries until 2014 but the initial year may differ among them. Hence, data before 1965 were not considered in the panel analysis[39]. Furthermore, to avoid the impacts of the late 2000s international crisis, the income elasticities of demand are estimated using data until 2007.

Data in the COMTRADE database are available in U.S. dollars at current prices. Although other estimates of multisectoral Thirlwall's law did not take into account change in relative prices across sectors[40], this procedure is necessary here because the functions of exports and imports in the model consider growth rates in constant prices, so that changes in relative prices could bias its results. Exports and imports of consumption goods and low-tech manufacturing were deflated using the price index of household consumption, whilst the price index of capital formation was used to deflate imports and exports of capital goods and high-tech manufacturing. Both indices are available in the Penn World Table (Feenstra *et al.*, 2013). Imports were deflated using each country's price indices, and exports were deflated using the US price indices[41]. Further, data on the exports and imports of natural resources and primary products were deflated using the free market commodity price indices, available in the UNCTAD Statistic Database (UNCTAD-Stat) [42].

Additionally, to obtain countries' and regions' GDP growth rates, the World Development Indicators (World Bank) is used. All series in this database may be used without further modifications once they are available from 1960 to 2011 in U.S. dollars at constant prices for all countries.

It is also important to note that although changes in exchange rates are not relevant to explaining the growth rates of trade flows in this model, it is desirable to use changes in real exchange rates while estimating income elasticities (McCombie, 1997). In order to do so, data from 1950 to 2010 for countries' GDP price indices are used. These data are available in the Penn World Table (Feenstra *et al.*, 2013).

Thereby, equations (2.22) and (2.23) are estimated to obtain the income elasticities of demand for imports and exports, respectively:

[39] In the time-series analysis, data from 1962 to 2007 were applied, once this data is available for Brazil.

[40] Gouvea and Lima (2010), Romero *et al.* (2011) and Tharnpanich and McCombie (2013) applied aggregate deflators as price deflators for sub-sectors in their classification are not available.

[41] The choice of the US price indices relies on the assumption that their import prices are a reference to all other countries' export prices.

[42] Appendix A presents details on the correspondence used to deflate these data.

$$\ln(M^i_{at}) = \pi^i_a \ln(Y_{at}) + \psi^i_a \ln(RER_{at}) \tag{2.22}$$

and

$$\ln(X^{ij}_{at}) = \varepsilon^{ij}_a \ln(Y_{jt}) + \eta^{ij}_a \ln(RER_{at}) \tag{2.23}$$

where η is the price-elasticity of demand for exports, X is the exports from country a to country j, and RER is country a's real exchange rate to the US.

As the index i stands for sectors, and j stands for low and middle-income counties (LIC) and high-income countries (HIC), there will be nine specifications for each country under consideration: three of them coming from equation (2.22) and six of them coming from equation (2.23).

2.4.2 Applying the model to Brazil

As discussed in McCombie (1997), some series used in this model might have been generated by a non-stationary process, so that an estimation of these equations by Ordinary Least Squares (OLS) could be spurious. Therefore, the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests were used to investigate the presence of unit roots, and for the non-stationary variables, a Johansen's co-integration test was also conducted.

According to the tests results, two different strategies were employed in order to estimate the elasticities of interest[43]. First, for the variables (log-linearized) that proved themselves to be stationary, a basic OLS regression is applied. Then, in the cases where the unit root tests have indicated non-stationary variables, but the series are likely to co-integrate according to the Johansen test, an Error-Correction Mechanism (ECM) is estimated[45].

For the case in which the series are non-stationary and do not co-integrate, some authors suggest the estimation of elasticities through the OLS method in first differences. However, according to McCombie (1997), this method is not useful because long-term relationship between variables is lost. Nevertheless, according to Johansen's test, all non-stationary variables proved to be co-integrated, showing that there is a long-term relationship between income growth and imports and exports, as expected[46].

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[45] Johansen's model and lags specification is based on Schwartz-Bayesian Information Criteria (SBIC), while the model and lags specification for the ECM estimation is based on SBIC and Log-Likelihood (LL).

[46] Appendix B contains the estimation results and the method employed for each series.

Looking carefully into the estimated income elasticities of exports for Brazil (first two columns of Table 2) we see that the coefficients associated with capital and consumption goods are greater than the ones for natural resources regarding both groups of trading partners (low/middle- and high-income countries)[47]. This result suggests that for both groups of partners a more rapid growth accentuates more significantly the demand for non-resource based products. On the other hand, the difference between the two groups of countries demonstrates that they have different demand structures in their trade relationship with Brazil. Although a marginal increase in the low/middle-income countries' growth rate stimulates the demand for natural resources and capital and consumption goods similarly (the difference between the elasticities is not statistically significant), a marginal increase in the high-income countries' growth rate stimulates these demands differently: capital and consumption goods grow significantly faster than natural resources (at the 1% level).

Furthermore, the last column of Table 2.2 shows that, for both consumption and capital goods, the Brazilian income elasticity of demand for exports to high-income countries is significantly higher than to low/middle-income countries, whilst, for natural resources, the result is the converse.

Regarding natural resources exports, we have that if high-income countries' growth rate increases by 1 p.p., Brazilian exports would increase by only 1.36%, but, if low/middle income countries' growth rate increases by 1 p.p., Brazilian natural resource exports would increase by 2.19%. Thereby, once Brazil is predominantly an exporter of these products, we shall conclude that the faster growth of low/middle-income countries during the 2000s have significantly contributed to its total exports growth, and consequently to reducing the balance-of-payments constraints.

Taking the higher growth rate of low/middle-income countries as permanent, and considering that this phenomena has resulted in an structural change in the world demand in favour of natural resources, it is now investigated whether the increase in the Brazilian growth rate during the 2000s is conjectural or due to this change in world demand and, consequently, in Brazil's balance-of-payments dynamics. Notice that it is now possible to input these estimated income elasticities for Brazil into equation

[47] Surprisingly, contradicting Engel's law, the import and export income elasticities of natural-resources are greater than one. This result, which is the same found by other studies, such as Gouvea and Lima (2010), is probably due to the period considered for estimation, when the share of trade in GDP has grown in almost every country. If one estimates the demand elasticity rather than import and export income elasticities, the elasticities will probably be lower than one. For this study, however, it is important to highlight that even though these elasticities are greater than one, they are lower than other sectors' elasticities.

Table 2.2: Income elasticities of demand – Brazil (1962-2007)

	ε^{LIC}	ε^{HIC}	π	$\varepsilon^{HIC} - \varepsilon^{LIC}$
Natural Resources (NR)	2.19***	1.36***	2.34***	-0.83***
	(0.12)	(0.12)	(0.34)	(0.17)
Consumption Goods (CG)	2.67***	3.53***	3.41***	0.86*
	(0.38)	(0.28)	(0.56)	(0.47)
Capital Goods (KG)	2.70***	4.77***	3.51***	2.07***
	(0.18)	(0.24)	(0.66)	(0.31)
CG − NR	0.48	2.17***	1.06	
	(0.40)	(0.31)	(0.65)	
KG − NR	0.51**	3.41***	1.16	
	(0.22)	(0.28)	(0.74)	

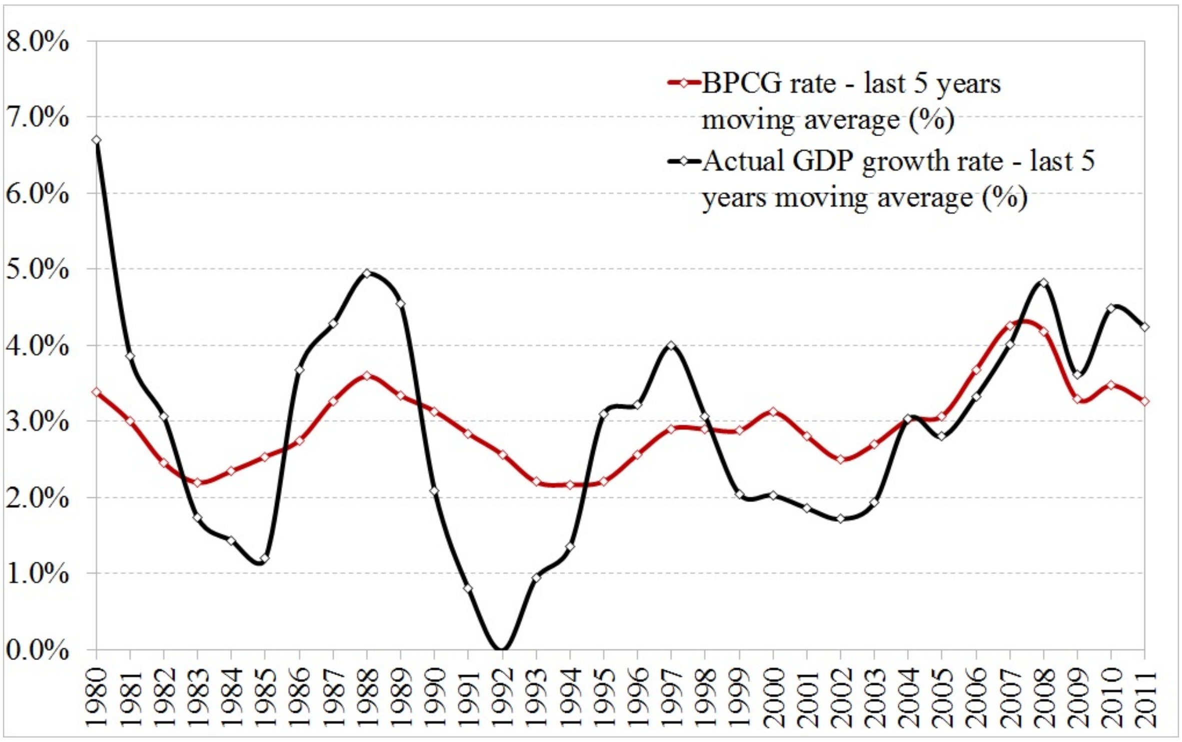
ε^{LIC}: Income elasticity of demand for exports to low/middle-income countries; ε^{HIC}: income elasticity of demand for exports to high-income countries.
*: significant at the 10% level; **: significant at the 5% level; ***: significant at the 1% level.

(2.20) in order to obtain Brazil's BPCG rate annually and its path over the period 1980-2011. This trajectory is plotted in Figure 1 together with actual GDP growth rate (five years moving average).

Once the BPCG models intend to predict countries' growth rates in the long run, the estimated BPCG rate path is expected not to predict the fluctuation of the GDP growth rate but to be a lot more stable. As we can see in Figure 1, during the 1980s and 1990s Brazil's actual GDP growth rate floats around the estimated trajectory, indicating that these short term fluctuations are likely to be conjectural. In the 2000s, however, the model was able to predict the actual growth rate's substantial increase (from around 2.5% to a peak of 4.0% in 2007), so that both series rise together. This outcome denotes that the faster growth in this last decade seems to be caused by a structural change, rather than better short-term economic scenery. Based on this work's approach, therefore, we may interpret such phenomena as a result of a better balance-of-payments condition, as Brazil's export structure is based on natural resources and LIC start growing faster during this same period.

Araujo and Lima (2007)'s multisectoral model (presented in Section 2.2) has also been applied to several developing countries (including Brazil) by Gouvea and Lima (2010). This empirical study has demonstrated that Araujo and Lima's model identifies the fall in Brazil's GDP growth rate during the 1990s as structural, explaining it by

Figure 2.1: Brazil: actual and estimated BPCG rates (1980-2011)



Source: WDI-WB; author's elaboration.

a drop in the estimated BPCG rate. According to Gouvea and Lima (2010), this downwards trajectory of the BPCG rate is because "the weighted elasticity of imports grew more than the weighted elasticity of exports over the period, which made for a fall in the ratio of trade income elasticities". It is important to note that the model developed here may also generate this same outcome, which arrives because both models divide the income elasticities in sectors. This division enabled the growth of high-tech imports (which have higher elasticities) during this decade to produce a drop in the income elasticities ratio, and thus in the calculated BPCG rate.

However, the events behind this drop in the long-term growth rate during the 1990s are distinct from the ones that took place in the 2000s. While the first structural change was mainly related to a change in the income elasticity of imports (due to the commercial openness in the early 1990s), the structural change in the 2000s was a consequence of the non-homogeneous growth among trading partners with different income elasticities. This second mechanism is not captured by Araujo and Lima (2007)'s approach.

In order to consider the impacts of this structural change in world demand the present model has also divided the income elasticities of exports by trading partners. By doing so, it is then possible to conclude that Brazil's growth in the 2000s was not only a consequence of the wealth effects of favourable terms of trade (such as identified in Canuto *et al.* (2013)) but also caused by structural changes in the balance-of-payments dynamics.

Furthermore, the model developed here is also capable of decomposing Brazil's sources of growth into high-income countries' and low/middle-income countries' contribution. Figure 2.2 shows the impact of the demand for Brazilian exports of each group of countries on the BPCG rate. The contribution of each group of country is obtained by considering equation (2.20) for two commercial partners, as follow:

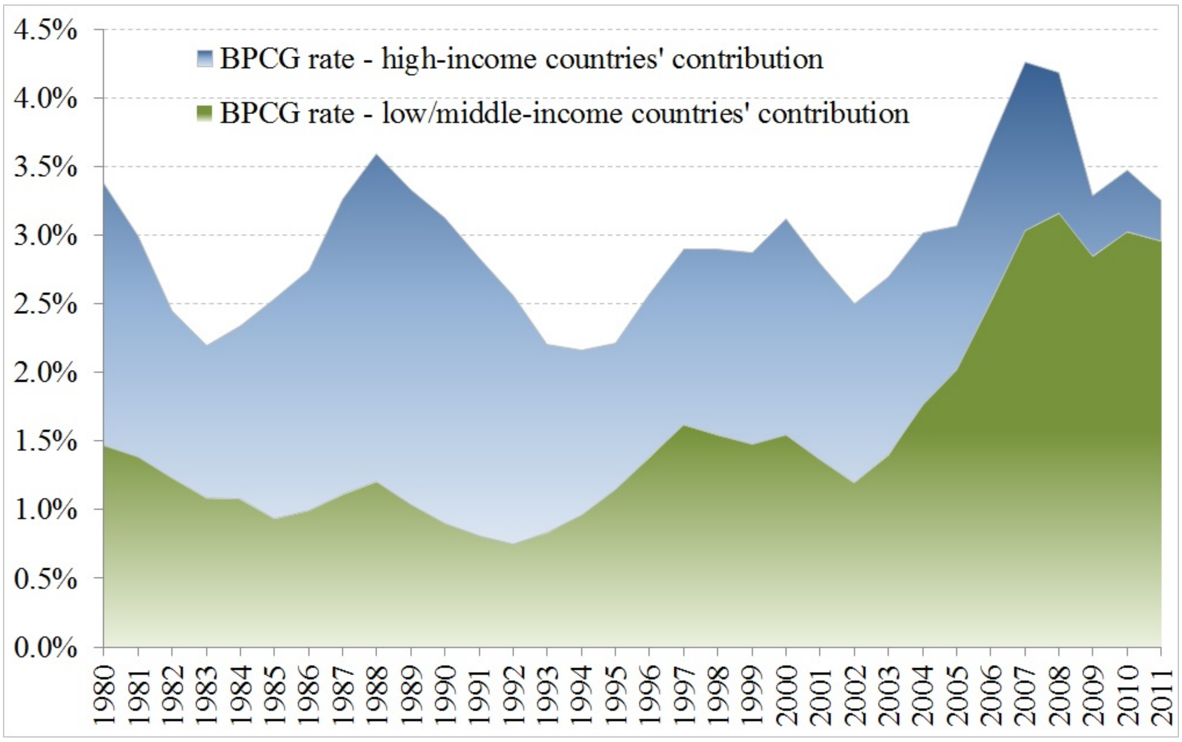
$$y_{B_t} = \frac{\sum_{i=1}^{N}(\phi_t^{i,LIC}\varepsilon^{i,LIC})}{\sum_{i=1}^{N}(\gamma_t^i\pi^i)}y_{LIC,t} + \frac{\sum_{i=1}^{N}(\phi_t^{i,HIC}\varepsilon^{i,HIC})}{\sum_{i=1}^{N}(\gamma_t^i\pi^i)}y_{HIC,t} \tag{2.24}$$

where the term in the left side presents the contribution of low/middle-income countries for the Brazilian BPCG rate, and the term in the right side, presents the high-income countries' contribution. Because all countries are included in these groups, the BPCG rate is given by the sum of each contribution.

The figure shows that during the 2000s Brazil's BPCG rate has increased mainly due to low/middle-income countries' demand growth. Looking at this decade, it is possible to see a clear upward trend between 2002 and 2008 when low/middle-income countries' stronger demand for Brazilian exports affected Brazil's BPCG by 2.0 p.p. (these countries' contribution rose from 1.2% to 3.2%). Such growth in the BPCG rate was not even higher because high-income countries' contribution dropped from 1.3% in 2002 to 1.0% in 2008.

Additionally, Figure 2.2 evinces the negative impact of the international financial crisis on the Brazilian BPCG rate. From 2007 on, the high-income countries' growth rate has dropped significantly, leading to a decrease in the estimated rate. Although it does not mean that Brazil's actual growth rate is going to fall, the model indicates that, if the country keeps growing at the same rate as before the crisis, it might have difficulties in financing its imports and, eventually, face a balance-of-payments crisis.

Figure 2.2: Decomposition of Brazilian BPCG rate (1980-2011)



Source: WDI-WB; author's elaboration.

2.4.3 Applying the model to developing economies according to categories of demand

We have seen in the last subsection that the Brazilian faster growth in the 2000s was mainly due to a faster growth of low/middle-income countries. However, because Brazil is a natural-resource exporter[48], it is relatively more affected by a faster growth of these countries than economies that export manufactured products predominantly. Thereby, as we are interested in the general impact of these structural changes on economic growth, this same model has been applied to a larger set of developing countries.

This empirical analysis is based on a 46 years (1962 to 2007) panel data for 13 countries (6 from South America and 7 from South & East Asia). Rather than estimating the income elasticities for each country separately through a time-series model, a long-panel data methodology is employed to estimate equations (2.22) and (2.23). This

[48] According to Canuto *et al.* (2013) "[in the 2009-2011 period] the most important Brazilian exports are minerals (25.2 percent), foodstuffs (13.8 percent), and vegetables (12.3 percent)". Additionally, "Brazilian exports showed increased concentration for products in recent years. Commodity products gained significant relevance".

technique is preferable to analyse panels where both cross-section and time dimensions have a moderated size (Cameron and Trivedi, 2009:265-266), such as here.

Because in panels with a large number of periods the relationship between variables might be spurious, nonstationarity deserves attention. Hence, it is first desirable to investigate whether the time-series are stationary, and, if not but they have the same integration order, whether they are cointegrated.

Once distinct unit root and cointegration analysis are employed according to cross-sections' dependence, we start by applying the Pesaran (2004)'s cross-section's dependence test[49] to all series but high- and low-income countries' GDP[50]. Nevertheless, every series has shown to be cross-sectional dependent at the 1% significance level, and hence, in order verify the presence of unit roots, the Pesaran (2007) stationarity test was employed to all. The Pesaran (2007) test considers cross-sectional dependence through the inclusion of lagged differences in group-specific ADF regressions.

Because this test is very sensitive to number of lags and presence of trends, many specifications were considered. All series proved to be nonstationary (the null hypothesis of nonstationarity was not rejected) when trend is not included and at least one lag is included. However, when trend is included, results are somewhat controversial: the null hypothesis of nonstationarity was rejected for countries' GDP when three lags or less are included, as well as for natural resources imports and consumption goods exports to high-income countries when two lags or less are included. Thus, under a conservative approach, all variables but imports of natural resources and exports of consumption goods to high-income countries were considered to be nonstationary[51].

Different methodologies were employed depending on the result of the unit root test. Firstly, for those series that do not present unit roots (imports of natural resources and exports of consumption goods to high-income countries), income elasticities of

[49] The advantage of the Pesaran (2004)'s cross-sectional dependence test is that it can be performed for single nonstationary series, whilst Friedman's Chi-Square distribution and Frees's Q-distribution tests can only be used to analyse the residuals of stationary panel regressions.

[50] High- and low-income countries' GDP are not tested for CD because they are not country-specific, and hence time-series analysis are employed rather than panel analysis. As presented in the last subsection, high-income countries' GDP presents stationarity according to PP but not according to ADF test, whilst low-income countries' GDP has shown to have one unit root according to both.

[51] To those series analysed through time-series methods, the choice between ADF and PP tests was arbitrary depending on the series that is regressed to obtain the elasticity. In the case of the income elasticity of demand for CG exports, high-income countries' GDP was considered as stationary (following the PP test), whilst in the case of the income elasticities of demand for NR and KG exports, high-income countries' GDP was considered as nonstationary (following the ADF test).

demand can be straightforward estimated through a stationary long panel GLS method assuming individual fixed effects and a panel specific AR(1) autoregressive structure. This technique was chosen over a traditional panel estimation because the requirements regarding the error's structure can be lessened, namely: (1) the error terms in the model may be correlated over countries and over time; and (2) the error do not need to be homoscedastic nor cross-sectional independent.

Secondly, for all others series, which were considered as nonstationary, multiple error correction based cointegration tests (Westerlund, 2007) were performed first. The Westerlund's cointegration tests allow for heterogeneity and dependence across the cross-sectional units. As the null hypothesis of non-cointegration was rejected to all variables on at least one of Westerlund's tests, the possibility of a long-term relationship between exports or imports and income should be considered. Thus, the elasticities of import and export (the long-term relationship between these variables and income) were obtained through Panel Dynamic OLS (Kao and Chang, 2000) with lags and leads determined by Wald Chi-Squared Statistics. The advantage of this estimation method in comparison to the fully modified OLS (FMOLS) is that, for finite samples, the estimator's bias is reduced (Baltagi, 2013).

Table 2.3 presents the results for income elasticities of demand for exports[52], considering both the South American and the South & East Asian countries separately, and the whole sample.

Table 2.3: Income elasticities of exports according to categories of demand*

	South America		S&E Asia		All sample	
	ε^{LIC}	ε^{HIC}	ε^{LIC}	ε^{HIC}	ε^{LIC}	ε^{HIC}
Natural Resources (NR)	2.06	1.45	2.95	2.02	2.63	1.73
	(0.17)	(0.19)	(0.26)	(0.31)	(0.18)	(0.19)
Consumption Goods (CG)	2.89	3.29	3.08	3.95	2.92	3.56
	(0.36)	(0.30)	(0.36)	(0.15)	(0.25)	(0.14)
Capital Goods (KG)	2.59	3.38	4.61	6.00	3.93	4.81
	(0.28)	(0.31)	(0.40)	(0.71)	(0.34)	(0.50)

ε^{LIC}: Income elasticity of demand for exports to low/middle-income countries; ε^{HIC}: income elasticity of demand for exports to high-income countries.
(*): All results are statistically significant at the 1% level.

As is clear from Table 2.3, for South American and South and East Asian countries the income elasticities of exports tend to be higher in capital goods, and lower in

[52] Appendix B presents these results and the models' specification.

natural resource products. The income elasticities of demand range from 1.45 to 2.95 for natural resource exports, from 2.89 to 3.85 for consumption goods exports, and from 2.59 to 6.00 for capital goods exports. Thereby, an increase of the share of capital goods exports boosts these countries' BPCG rate. Moreover, similarly to the results obtained for Brazil (although in a lower scale), Table 3 shows that in both regions the income elasticities of natural resources is greater regarding exports to low/middle-income countries than to high-income countries. It means that the demand for these products would expand relatively more in face of a faster growth of low/middle-income countries than in face of a faster growth of high-income countries. In other words, although an increase in low/middle-income countries' growth rate accentuates the demand for capital goods relatively more than the demand for natural resources, if high-income countries experience this same growth the accentuation in the demand for capital goods is even higher than the demand for natural resources.

Considering the weight of these sectors in total exports, we verify some differences between the weighted income elasticities of these two groups when comparing them in terms of the exports' destination. Asian countries present higher elasticities in their exports to high-income countries because they export capital and consumption goods predominantly. Therefore, their exports increase relatively more if high-income countries are growing faster than low/middle-income countries. On the other hand, the opposite is valid in the case of South American countries. Because they export natural resources predominantly, their weighted income elasticities are higher to low/middle- than to high-income countries[53].

Furthermore, as low-income countries are growing faster than high-income countries since the early 2000s, this difference suggests that South American countries are benefiting from lower balance-of-payments constraints in the recent period. As South American countries export predominantly natural resources, and the elasticities of these goods are higher to low/middle- than to high-income countries, a faster growth of the former group compared to latter increases relatively more the demand for these goods. However, if low/middle-income countries' growth rates drop, South American countries shall be the most affected economies.

Finally, by analysing the estimated income elasticities of demand for imports some relevant issues also emerge. Such results are shown in Table 2.4. We may notice that the elasticities of demand are higher for capital goods than for natural resource imports

[53] In 2012, 66.1% of South American countries' exports were NR (on average), whilst they were only 15.6% of South & East Asian countries' exports.

in both groups of countries, meaning that, on average, a faster growth of an Asian economy or of a South American economy, both increase the demand for capital goods most rapidly. This result corroborates Gouvea and Lima (2010)'s findings, where the authors conclude that "when the values of the income elasticities are compared among sectors of the same country, it is seen that the technology sectors have higher income elasticities than the resource-based sectors".

Table 2.4: Income elasticities of imports according to categories of demand*

	South America	S&E Asia	All sample
Natural Resources (NR)	1.65	1.46	1.47
	(0.11)	(0.04)	(0.04)
Consumption Goods (CG)	1.84	0.63	1.19
	(0.30)	(0.20)	(0.17)
Capital Goods (KG)	1.36	1.19	1.73
	(0.18)	(0.18)	(0.13)

(*): All results are statistically significant at the 1% level.

Moreover, Asian countries' income elasticities for imports are lower than South American countries' elasticities, especially regarding capital and consumption goods. Hence, South American countries' BPCG rates tend to be lower than the Asian countries' rates, because the accentuation of demand for imports due to countries' faster growth is greater in South American economies than in Asian economies. Thereby, in order to boost their growth rate in the long run, South American countries must change their imports' structure (by reducing the share of capital and consumption goods) or, otherwise, they will need to rely on the high demand for their natural resources (which depends on low/middle-income countries' relatively fast growth) to compensate their high income elasticities of imports.

2.4.4 Applying the model to developing economies according to technologic intensity

The same methodology presented in the last subsection was employed here to estimate the income elasticities of demand for imports and exports according to sectors' technological intensity. First, series were tested for the presence of cross-sectional dependence. According to Pesaran (2004)'s test, all series present cross-sectional dependence, and thus they were tested for the presence of unit roots through the Pesaran (2007)'s test. According to this test, only primary products and low-tech exports to high-income countries were pointed out as nonstationary. Hence, income elasticities of demand for primary products and low-tech exports to high-income countries were estimated through a GLS fixed effects panel model, in which a panel specific AR(1) autoregressive structure was assumed, as well as heteroskedasticity and cross-sectional dependence. For the remaining series, the Westerlund (2007) error correction based cointegration tests were performed, and, again, the null hypothesis of non-cointegration was rejected by at least one of the Westerlund's tests in all cases. Thereby, all income elasticities of demand for imports were estimated through a Panel Dynamic OLS, as well as the income elasticities of demand for exports to low/middle-income countries and the income elasticity of demand for high-income exports to high-income countries.

Table 2.5 presents the results of these estimations. Similarly to what has been found for natural resources, the results for primary products show higher income elasticities of demand for exports to low/middle-income countries than to high-income countries in all samples[54]. This outcome reinforces the relevance of the low/middle-income countries' faster growth to explaining the increase in South American countries' growth rates during the 2000s. Because South America exports primary goods predominantly[55], a faster growth of low/middle-income countries relatively to high-income ones positively impacts South American countries' weighted income elasticity and, consequently, their BPCG rates.

Table 2.5: Income elasticities according to technologic intensity*

	South America			S&E Asia			All sample		
	ε^{LIC}	ε^{HIC}	π	ε^{LIC}	ε^{HIC}	π	ε^{LIC}	ε^{HIC}	π
Primary	2.11	1.35	1.71	2.26	2.00	1.42	2.15	1.51	1.54
	(0.26)	(0.14)	(0.16)	(0.30)	(0.15)	(0.12)	(0.20)	(0.09)	(0.10)
Low-tech	1.72	0.83	1.32	2.26	2.09	1.64	2.04	1.44	1.20
	(0.16)	(0.14)	(0.16)	(0.25)	(0.12)	(0.09)	(0.16)	(0.09)	(0.08)
High-tech	2.64	3.14	1.61	4.21	5.22	1.69	3.52	4.28	1.69
	(0.24)	(0.33)	(0.21)	(0.34)	(0.59)	(0.12)	(0.26)	(0.42)	(0.11)

ε^{LIC}: Income elasticity of demand for exports to low/middle-income countries; ε^{HIC}: income elasticity of demand for exports to high-income countries; π: income elasticity of demand for imports.

(*): All results are statistically significant at the 1% level.

The income elasticities of demand for high-tech exports and imports are greater than the income elasticities for low-tech in all cases[56], showing the importance of raising the share of high-tech in total exports and reducing the share of high-tech

[54] Only for South & East Asia, this difference is not statistically significant at the 5% level.

[55] Primary goods represented 54.9% of the South American countries' total exports (on average) in 2012 (UN-COMTRADE).

[56] Only for South American import elasticities, this difference is not statistically significant at the 5% level.

in total imports in order to increase BPCG rates. When elasticities of demand for high-tech are compared to elasticities of demand for primary products, similar results are found: all income elasticities of demand for high-tech are higher than for primary products, except regarding South America's imports[57]. Therefore, one may conclude that increasing the technological intensity of exports is crucial to reducing countries' balance-of-payments constraints, and, consequently, to guaranteeing high and sustained growth rates in the long run.

2.5 Concluding remarks

As we have seen along the chapter, the world is facing important changes in terms of its structure of production, and it implies in a structural change in world demand. Although the worldwide growth rate has been shrinking since the 1990s, it is not a homogeneous fall. While high-income countries' growth rates have been decreasing, low and middle-income countries are experiencing a faster increase in their growth rates, particularly from the 2000s on. This non-homogeneous process of growing has relevant implications on the world structure of demand, and thus in the trade flows, because the demand of each of these groups of countries is different.

In this context, the multisectoral version of Thirlwall's model (Araujo and Lima, 2007) is combined with Thirlwall's multilateral version (Nell, 2003) in order to render the impacts of these structural changes in world demand as endogenous. The good predictability of the multisectoral BPCG model (Araujo and Lima, 2007) is difficult to be refuted, once it is very efficient at treating structural changes inside countries as endogenous. These model, however, were not able to capture the previously treated changes, once these changes affect both the importance of each trading partner in growing and the sectoral structure of exports. Whence, the model developed in this paper render these changes as endogenous by dividing the income elasticities of demand for exports between different trading partners and sectors. By doing so, the non-homogeneous growth rates across countries with different structures of demand are incorporated in the model, and thus the impacts of structural changes in world demand on countries' BPCG rates can be calculated explicitly.

Further, the central thesis that income elasticities of demand vary according to trading partners' income levels and that such difference is relevant in explaining countries' growth rates is corroborated by an empirical investigation for Brazil. Although the impact of a faster growth of low and middle-income countries on Brazilian cap-

[57] Even though this difference is not statistically significant at the 10% level.

ital and consumption goods exports has shown to be lower to the impact of a faster growth of high-income countries, it increases the demand for Brazilian natural-resource products 60% more. This fact helps understanding why natural-resource exporters, such as Brazil, have been experiencing lower balance-of-payments constraints since the 2000s (when low/middle income countries start growing by 6.0% per year). This analysis, thus, suggests that these countries' higher growth rates in the last decade are not only due to a wealth effect caused by an increase in its terms-of-trade, but also due to a faster growth of low/middle-income countries' demand for natural resources.

When other developing economies are considered, however, the outcomes show that an increase of growth rates based on natural-resource exports might be unsustainable in the long run, once the income elasticities of demand for imports and for exports are higher for more technological advanced sectors. Because of that, structural changes in the composition of exports and imports turn into important determinants of the BPCG rate. This fact emerges because, although a country can achieve higher growth rates without facing balance-of-payments constraints if their trading partners are growing faster (such as Brazil during the 2000s), the share of capital and consumption goods exports must increase (or the share of the imports of these goods must decrease) in order to boost its growth rate in the long term without relying on its trading partners' growth.

As a final remark, it is highlighted that the contribution of this study on the importance of rendering structural changes in the world demand as endogenous in BPCG models does not deplete the subject. Hence, further studies are needed in order to fully understand the complexity of such changes and to what extent they are relevant in the long run. For example, if high-income countries' growth rates start increasing (or low/middle-income countries' growth rates start decreasing), these structural changes will no longer be an issue, once the world growth would be homogeneous.

Likewise, as low/middle-income are growing by 6.0% per year, their income elasticities are approaching high-income countries as their income level increases, which tends to lower the relevance of non-homogeneous growth among countries. Thereby, in the present economic scenery, natural resource exporters could take advantage from lower balance-of-payments constrains (caused by the faster growth of developing countries) by shifting their structure of production towards more technological sectors. This is due to the fact that the increase of high-tech exports (and the decrease of high-tech imports) is the ultimately determinant of a country's growth rate in the long run.

Chapter 3

Estimating Verdoorn's law across countries in different stages of development

3.1 Introduction

One of the main explanations for differences in countries' growth rates relies on the existence of static and dynamic increasing returns to scale. The centrality of this explanation is at the root of both the new growth theory and the Kaldorian approach.

New growth models criticised the neoclassical/Solow model by assuming that productivity growth is determined endogenously. They argued that although firms may be faced with constant returns to scale, regions and countries present increasing returns due to externalities generated by capital accumulation (Romer, 1986) or by allocation in specific activities, such as R&D and education (Lucas, 1988; Romer, 1990). This assumption has shifted the focus of the neoclassical models from exogenous technological changes to the externalities generated by the growth process itself.

These models, however, have paid little attention to sectoral specificities to explaining differences in countries' growth rates, as well as neglecting the importance of demand growth. As discussed in the first chapter, although these models emphasise the importance of some activities, such as R&D, increasing returns are not associated with the size of one specific sector, such as manufacturing, agriculture or services (Palma, 2005). Furthermore, productivity is ultimately constrained by the accumulation of production factors and, in these models, these factors are determined exogenously rather than induced by demand growth (McCombie, 2002; Dutt, 2006).

In contrast with the new growth theory, the Kaldorian approach stresses the existence of increasing returns to scale in some sectors and the importance of demand as an ultimately source of growth. Different from the endogenous growth theories, Kaldor (1966; 1972) stressed that sectors have different degrees of increasing returns, and thus countries may grow at different rates due to their sectoral structure of production. Moreover, because capital is a produced means of production and investment responds to demand, output growth determines the rate of capital accumulation. Hence, endogenous technological change is induced by demand growth instead of constrained by the supply of production factors, such as in the new growth models.

The first chapter emphasised some reasons why sectoral growth rates might explain countries' growth rate differences. This chapter focuses on Kaldor's second growth law (also known as Verdoorn's law), which argues that manufacturing growth promotes a faster growth of productivity of the sector itself. Verdoorn (1949) has emphasised a long-term association between faster output growth and growth of productivity in manufacturing, and showed such empirical relation for a cross-section of countries. Kaldor (1966) went further and argued for a causal relationship. According to him, a faster output growth causes a faster growth of productivity (McCombie and Thirlwall, 1994: 168) due to static and dynamic increasing returns. This statement is at the heart of the cumulative causation models. As production grows due to the increase of the extent of markets, the scope for specialisation increases, and it stimulates the growth of productivity (due to division of labour). Thereby, in a circular process that involves both the supply and demand sides, productivity growth increases output via market extension, which, in turn, stimulates productivity growth (McCombie, 2002).

Although in his 1966 lecture Kaldor argued that the UK (a developed economy with no surplus labour in non-manufacturing activities) was de-industrialising because it was suffering from "premature maturity", which has exhausted its potential for fast growth, he extended this argument for countries in different stages of development (Kaldor, 1966; 1967). Nevertheless, this extension depends on the consideration that different industries inside manufacturing, such as capital goods, might have different degrees of increasing returns and income elasticities according to countries' stages of development[58]. Because individual industries take different advantages of production and demand factors, such as market extension, skilled labour and innovation, one

[58] After the early stage of development, where agriculture investment is the major important source of industrial growth, Kaldor (1966, 1967) define four stages of development based on foreign demand. First, a country has to promote import-substitution of consumption goods; second, promote exports of these goods; third, promote import-substitution of capital goods; and, in the most advanced stage, promote exports of capital goods.

cannot expect that these industries have the same characteristics in developing and developed countries.

Therefore, this chapter analyses industries inside manufacturing in terms of their dynamic increasing returns to scale (Verdoorn's law) across countries controlling for their income per capita. The aim is to identify those industries that present a higher degree of increasing returns and thus which are able to boost economic growth both for developing and developed countries. This analysis aims to demonstrate the importance of the sectoral structure to productivity growth and thus how specialisation in some industries can boost economic growth in the long run according to countries' stages of development.

Several studies have analysed the existence of increasing returns across manufacturing industries, for example: McCombie and De Ridder (1984), McCombie (1985), and, more recently, Angeriz *et al.* (2009). Essentially, they found evidence of high increasing returns to scale at the industry level, especially when the specification attempts for dynamic increasing returns. However, once they consider a specific country or a group of developed countries (e.g., states of the USA or regions of the European Union), they cannot infer any conclusion about the importance of these industries according to countries' stages of development. In this vein, although these studies are used for comparison, this chapter goes further and analyses the degree of increasing return for both developed and developing countries at the industry level. Verdoorn's law is estimated across a range of countries, including those with high-income levels and low and middle-income levels, in order to contrast the results and provide an explanation for the convergence (or divergence) in countries' productivity through sectoral specificities.

This chapter is organised as follows. The next section presents the debate on Verdoorn's law different specifications, focusing on the supply- and demand-approaches for the existence of increasing returns to scale, the static-dynamic Verdoorn's law paradox and the distinction between Verdoorn's law and Okun's law. Section 3 presents a method to estimate Verdoorn's law from the supply- and demand-side approaches, contrasting its assumptions. Moreover, it incorporates human capital and technological gaps into the specification of Verdoorn's law. Section 4 estimates this law contrasting the degree of increasing returns obtained through the supply- and demand-side specifications. Section 5 presents the results of the estimation according to countries' stages of development for each individual industry, as well as according to technological intensity and categories of demand. Section 6 discusses the consequence of this chapter's findings for the growth literature and provides the concluding remarks.

3.2 Verdoorn's law specifications and interpretations

Based on countries' data for two long periods (between 1870-1914 and 1914-1930), Verdoorn (1949) established a long-term relationship between industrial output growth and productivity growth, by estimating the following equation:

$$q = \lambda + by \tag{3.1}$$

where q is industrial productivity growth, y is industrial output growth, λ is the rate of technical progress not explained by output growth and b is the elasticity of productivity with respect to output, known as the Verdoorn coefficient.

Verdoorn found a coefficient of approximately 0.45 (with limits of 0.41 and 0.57) for the elasticity of productivity with respect to output. Despite suggesting that one could have expected these results a priori because division of labour depends upon the volume of production, which, in turn, creates scope for rationalisation and productivity growth, Verdoorn did not establish a clear causal relationship between these two variables. The author emphasised an association between output and productivity growth, but he did not discuss the mechanism behind this process. Kaldor (1966), on the other hand, argued for a one-side causal relationship between these two variables. He stressed that Verdoorn's findings reflect a dynamic rather than static relationship between output and productivity growth primarily because technological progress enters into it. According to him, faster growth rates of output induce faster productivity growth due to the existence of dynamic increasing returns to scale in manufacturing[59].

3.2.1 Supply- and demand-side specifications

In a series of papers, Rowthorn (1975a; 1975b) and Kaldor (1975) discussed about the most adequate specification of this law based on theoretical and empirical issues. According to Rowthorn (1975a), this law should have estimated explicitly the elasticity of productivity in relation to employment in order to verify to what extent productivity growth is constrained by labour force, which Kaldor assume for the UK. Hence,

[59]Some authors argued that this relationship could be seen from productivity growth to output growth because increases in productivity reduce prices, and it might increase the growth rate of demand (Salter, 1966). Nevertheless, according to Kaldor, in this view productivity is mainly to be explained by autonomous technical progress, but if this is true, how can we explain large gaps in productivity growth across different countries for such long periods? Hence, Kaldor argues that this relation can only have one direction of causality: from output to productivity.

equation (3.2) should be estimated, rather than (3.1), as follows:

$$q = -\lambda + dl \tag{3.2}$$

where l is employment growth and $d = (1 - b)$ is the elasticity of output to employment. By doing so, Rowthorn found that there is a positive Verdoorn coefficient, but it depends on the inclusion of Japan in the analysis[60].

Kaldor (1975) replied arguing that Rowthorn's estimation is correct only if one considers the factors of production as exogenous to output. However, output, rather than the labour or capital, is the exogenous variable. According to him, capital required for industrial production is self-generated by output growth once investment responds to demand growth, and labour is absorbed by manufacturing during the process of industrialisation because it has no true opportunity cost in agriculture and services. In this sense, Kaldor argued that the original specification was the most appropriate way to estimate Verdoorn's law, once output, which is exogenous, is the explanatory variable[61].

The main conclusions this discussion brought to the debate are twofold.

Firstly, the results of estimation for the existence of increasing returns to scale depends on the variables considered as exogenous. On the one hand, the demand-side specification assumes output as exogenous, which implies that causation runs from growth of demand to productivity growth. The supply-side specification, on the other hand, assumes supply of factors as exogenous and, thus, causation running from the availability of factors to productivity.

Secondly, because output, employment and productivity are conjunctly determined, Verdoorn's law has to be estimated through instrumental variables to prevent the estimation from the simultaneous equation bias. Both Kaldor's and Rowthorn's specifications rely on the assumption that the explanatory variable is exogenous. However, due to the notion of cumulative causation, productivity growth is endogenous to output growth (Verdoorn's law), but output growth is, in turn, endogenous to productivity growth, once productivity affects countries' or regions' price-competitiveness

[60] Kaldor estimated Verdoorn's equation, finding a coefficient of 0.484 for the elasticity of manufacturing productivity to output, which is very similar to the one found by Verdoorn. Moreover, he also estimated the relationship between employment and output growth, finding a coefficient of 0.516 for the elasticity of employment to output growth, which has confirmed Verdoorn's law.

[61] Kaldor (1975) suggested, alternatively, to regress output on employment, rather than on productivity. In this approach, the Verdoorn coefficient is given by one minus the estimated coefficient.

and thus their exports. Hence, these variables are simultaneously determined, and one should instrumentalise the explanatory variable to estimate this law correctly[62].

According to Angeriz *et al.* (2008), the distinction between supply- and demand-side specifications is relevant firstly because estimating Verdoorn's law from different approaches produces different results. Moreover, it is necessary to consider these different views because it depends on a priori theoretical arguments. Neoclassical and endogenous growth approaches assume that savings determine investment, and, consequently, the estimations produced by the supply-side specification are more appropriate to estimate the degree of increasing returns. On the other hand, the Kaldorian approach sees investment as being determined by the acceleration mechanism rather than by savings and, consequently, the demand-side specification is the most appropriate.

Based on this distinction between supply- and demand-side specifications, many authors attempted to estimate Verdoorn's law from these two approaches. McCombie and de Ridder (1984), for example, constructed series of capital stock with the aim of control for the growth of non-labour inputs, and estimated this law for total manufacturing for 49 states of the US. Their results show that both specifications corroborate the presence of increasing returns to scale in manufacturing, even though it is greater if one assumes demand-side specification. While supply-side specification with growth of employment as a regressor gives a value of 1.33, Kaldor's specification with growth of output as a regressor gives a value of 1.45. Moreover, following Kennedy and Foley's (1978) suggestion, the authors also estimate this law based on total factor inputs rather than employment. The results for both specifications were slightly larger than the traditional approach, corroborating for the existence of increasing returns to scale in manufacturing.

More recently, Angeriz *et al.* (2008) estimated this law based on demand- and supply-side specifications for EU regional data by controlling for spatial correlation. The authors found values for the degree of increasing returns statistically different from the unity when output is the regressor. However, different from the results obtained in the former study, they found non-significant results when factor inputs are the regressor, indicating that manufacturing may be subject to diminishing returns to scale. These results brought back the importance of distinguishing the supply and demand approaches. They show that if one assumes that output is exogenous to

[62]See McCombie (2002:95-96) for a detailed discussion about simultaneous equation bias in both estimations.

productivity, such as predicted by the demand-side version, manufacturing is subject to increasing returns, but if one assumes capital and labour as exogenous, such as predicted by the supply-side view, the existence of increasing returns is not found.

3.2.2 The static-dynamic Verdoorn's law paradox

Verdoorn's law asserts that a faster growth of productivity is positively related to a faster growth of output. In this sense, it is related to dynamic rather than static increasing returns to scale. This dynamic relationship, however, can be derived from a static production function, such as shown by Black (1962). Thereby, estimating the degree of increasing returns using a production function with variables expressed in logarithm should give the same results as estimating it directly through Verdoorn's original specification.

However, McCombie (1982) shows that estimating this law through these two different methods gives different results. According to him, the Verdoorn's law obtained by exponential growth rates (which reflects Verdoorn's original approach) gives support for the existence of increasing returns to scale, whilst estimations based on log-level values suggest constant returns to scale. This controversial result is known as "static-dynamic Verdoorn's law paradox", and it was found in many other studies. Theoretically, despite having different meanings, the distinction between dynamic and static returns to scale is irrelevant for estimation purposes. Nevertheless, empirical results are different when it is estimated using log-level values (the static approach) and exponential growth rates (the dynamic approach).

McCombie and Roberts (2007) argue that if Verdoorn's law is correctly specified, the paradox can be attributed to spatial aggregation bias. According to them, when data are aggregated to regional level (for example, countries and states), the relationship between the variables come to be between their averages rather than individual values. This bias occurs when Verdoorn's law is estimated through log-level values, and thus the dynamic law is the correct specification. By using a dataset constructed for simulation, the authors estimated Verdoorn's law from both specifications. Although the data was constructed assuming increasing returns, they show that the Verdoorn coefficient was statistically different from zero in the estimation based on the dynamic version, such as expected, but it was not when Verdoorn's law was estimated through the static version. Based on this, they argued that regardless the true degree of increasing returns to scale, the static specification estimated using cross-sectional aggregate regional data always indicates the existence of constant returns, once all productivity growth is captured by the intercept. They show mathematically that due to the aggregation of data, the estimated degree of increasing returns is (statistically) equal to the unity and thus Verdoorn coefficient is equal to zero independently of its true value.

By using aggregate time-series data, on the other hand, McCombie and Roberts show that the static-dynamic Verdoorn's law paradox does not arise. In contrast to cross-sectional data, in this specification, both the static and the dynamic Verdoorn's law give relatively unbiased estimates of the degree of increasing returns. When one estimates this law through panel data, the same problem of cross-sectional data is obtained if random effects are assumed, but the paradox does not arise when one-way or two-way fixed effects are assumed. Thereby, estimating Verdoorn's law through cross-sectional log-level values or random effects panel data provides biased estimations for the degree of increasing returns. The correct specification should consider exponential growth rates or, alternatively, it must be obtained by means of aggregate time-series or fixed effects panel data techniques.

3.2.3 Verdoorn's law and Okun's law: long- and short-term relationships

An important issue that arises when Verdoorn's law is being estimated is that it is a long-term relationship between output and productivity growth rather than a short-term relationship. This law is an attempt to provide an explanation for technological changes by assuming that they are induced by output growth. Essentially, productivity increases due to technological changes and thus there is a positive relationship between output growth and productivity growth.

Notwithstanding, Okun's law addresses the same relationship. According to this law, output is negatively related to unemployment. The impact of an increase (or decrease) in output is not completely absorbed by changes in employment in the short-term, and thus employment reacts more slowly to output fluctuations. Consequently, there is a procyclical relationship between productivity and output growth. Because a faster growth of output increases employment but at a lower rate, productivity reacts positively to output growth. Thereby, in the upwards cycle productivity increases, whilst it decreases in the downwards.

The difference between Okun's law and Verdoorn's law is that the latter emphasises a long-term relationship between these two variables, whilst the former attempts to analyse a short-term relationship. In Verdoorn's law, changes in productivity are not a response to fluctuations in the capacity utilisation, but a response to technological improvements. Hence, the correct specification of this law must take account of this possible source of bias. If one estimates this law based on exponential growth rates it is important to consider time units long enough to avoid estimating cyclic fluctuations. Moreover, when it is estimated by log-level values, series must be long enough to obtain the long-term relationship between variables rather than the impact of shocks[63].

Thereby, a distinction has to be made between these two approaches when one estimates Verdoorn's law. Although a positive relationship between output growth and productivity growth can be due to short-term fluctuations or to technological changes, these approaches suggest very different conclusions about economic systems. If a short-term relationship is verified, it means that employment is more rigid than output and thus productivity is procyclic, such as predicted by Okun's law. On the other hand, if the long-term relationship is verified, it means that technological change is induced by output growth, such as suggested by Verdoorn's law.

3.3 Methods and data

3.3.1 Estimating Verdoorn's law: supply- and demand-side specifications

Section 3.2 discussed the problems of estimating the long-term relationship between faster growth of production and growth of productivity through equations (3.1), such as Verdoorn (1949) did. Because it is not explicit in his approach whether demand or factors inputs are exogenous, applying equation (3.1) to estimate Verdoorn's law only shows the relationship between these two variables, instead of presenting an economic explanation for productivity growth.

Furthermore, although Verdoorn's law addresses the importance of technological change to promote growth, if we assume that investment is induced by demand growth, a faster growth of output has two impacts on labour productivity. On the one hand, an increase of output increases capital-labour ratio, which has a direct impact on productivity due to the increase of "the same kind" of capital to the production process. On the other hand, output stimulates investment in new technologies and thus labour productivity increases through technological change, which is Kaldor's explanation for

[63] Alternatively, some studies have adjusted output growth for changes in the capacity utilisation to estimate Verdoorn's law, such as Harris and Liu (1999).

Verdoorn's law. In this sense, to estimate Verdoorn's law from a Kaldorian perspective, it is necessary to include controls for the growth capital stock induced by demand[64].

Hence, the regressions presented in Section 3.2 are unable to estimate correctly the degree of increasing returns, as well as to differentiate between these two causal relationships. A more appropriate specification must consider explicitly the direct impact of adding more of the same capital and the impact of technological changes stimulated by the induced investment through an aggregate technical progress function[65].

It is now well established that aggregate production functions are merely picking up an accounting identity, and data will suggest constant returns to scale regardless of the actual degree of increasing returns (Felipe and McCombie, 2013). However, Verdoorn's law derived from a production function can still be interpreted as showing increasing returns to scale, although not within the conventional framework. According to McCombie and Spreafico (2015), theoretically, an aggregate production function does not exist, and thus one cannot interpret the intercept as the separate contribution of exogenous technological change to growth, as well as the Verdoorn coefficient should not be interpreted as a measure of increasing returns to scale *per se*. All that can be said is that a faster growth of output leads to a faster growth of productivity due to many factors, such as induced technological change and greater efficiency in the use of resources. Hence, once the coefficients are not interpreted as the marginal contribution of the various factors that determine growth, such as in neoclassical approach, Verdoorn's law can be estimated based on this approach. Thereby, this methodology is applied here for expositional reasons[66].

Based on McCombie (2002), it is assumed that firms' output growth is determined by growth of capital, labour and technical progress, as follows:

$$y_i = \lambda + ak_i + (1 - a)l_i \tag{3.3}$$

where λ is the rate of technical progress, y, k, and l are the growth rates of output, capital and labour of firm i, and a and $(1 - a)$ are the output elasticities of capital

[64]Under the assumption of constant capital-output ratio, a stylised fact shown by Kaldor (1961) for the long term, Verdoorn's law can be reduced to equation (3.1). However, it is not assumed here because short-term variations in capital-output ratio can affect the estimation of Verdoorn's coefficient.

[65]McCombie and Spreafico (2015) show that Kaldor's aggregate technical production function can be derived from an aggregate production function, although these two functions have different interpretations

[66]McCombie (2002) presents a detailed discussion about problems and advantages of this theoretical approach.

and labour.

According to the Kaldorian view of Verdoorn's law, the rate of technical progress is determined endogenously by the output growth. Hence, the rate of technical progress at the industry level is given by:

$$\lambda = \bar{\lambda} + \zeta y \tag{3.4}$$

where $\bar{\lambda}$ is the exogenous technical progress, and ζ is the elasticity of induced technical progress in respect to the industry output. Although many authors have emphasised the existence of induced technical progress in different forms, such as Arrow (1962), who stressed the importance of learning-by-doing at the firm level, and Young (1928), who focused on increasing returns on the macro level, here induced technical progress is due to the existence of localisation economies, once it is seen at the industrial level[67].

Replacing (3.4) in (3.3), and assuming that capital-output ratio and labour output ratio are identical between firms in the same industry, we have:

$$y = \nu[\bar{\lambda} + ak + (1-a)l] \tag{3.5}$$

where $\nu = \frac{1}{1-\zeta}$ is the degree of increasing returns. In this equation, the importance of factor accumulation for economic growth is explicit. In contrast to equation (3.2) and (3.3), where one only can see explicitly the direct impact of factors accumulation on output growth, here it is possible to see that accumulation of capital and labour increases output growth by stimulating endogenous technical progress if the degree of increasing returns, ν, is greater than one.

Re-arranging equation (3.5) it is possible to present Verdoorn's technological progress function augmented for capital accumulation as follows:

$$q = \frac{\bar{\lambda}}{a} + \frac{\nu a - 1}{\nu a} y + \frac{\nu(1-a)}{\nu a} k \tag{3.6}$$

[67]There are many explanations for the existence of increasing returns to scale. Krugman (1991; 1998), for example, emphasises the effects of external economies of scale. According to him, the geographical clustering of activities can result in *localisation economies*. Clustering facilitates research and innovation in an industry, as well as the exchange of ideas and knowledge between firms. Furthermore, the author also stresses the importance of Marshallian sources of external economies, such as market-size effects (backward and forward linkages), a thick local labour market, especially for specialised skills, and information spillovers.

According to the demand-led approach for Verdoorn's law, capital accumulation is not determined exogenously by savings. Instead, it is induced by demand growth. Hence, equation (3.6) can be rearranged to present a technological production function where the impact of change in capital-output ratio on productivity is explicit, rather than capital accumulation itself:

$$q = \frac{\bar{\lambda}}{a} + \frac{\nu - 1}{\nu a} y + \frac{1 - a}{a}(k - y) \tag{3.7}$$

In this equation, productivity is explained by the impact of exogenous technological change, output growth and the increase in capital-output ratio. The Verdoorn coefficient can be obtained directly from this equation assuming ex-ante that capital and output grow at the same rate in the long run, such presented by Kaldor (1961). By doing this, equation (3.7) can be reduced to equation (3.1), which is the original Verdoorn's law. Alternatively, changes in capital-output ratio can be used as a control for the direct impact of output growth on productivity. In this approach, this law is presented enabling for changes in capital-output ratio, and, if one assumes that these changes are not induced by output growth, the Verdoorn coefficient, which is the long-term impact of output growth on productivity, can be expressed as[68]

$$b = \frac{\nu - 1}{\nu a} \tag{3.8}$$

This methodology is important because it considers explicitly output growth as exogenous to the growth of labour productivity, and thus it implies that demand factors are the main drivers of the accumulation process. Essentially, estimating equation (3.8), we obtain the degree of dynamic increasing returns under the assumption that output is exogenous (determined by demand for local products) and the factors of production (capital and labour) are endogenous, such as it is established by the demand-side version (or Kaldorian version) of Verdoorn's law.

Another possibility of estimating the degree of increasing returns is by re-arranging equation (3.5) to consider explicitly the impact of factor accumulation on labour productivity, as follows:

[68] Many studies, such as Angeriz *et al.* (2008, 2009), estimate the Verdoorn coefficient regressing output on total factor productivity. The advantage of this approach is that there is no need to assume capital-output ratio as exogenous to output growth to obtain the Verdoorn coefficient, such as assumed in this work. Nevertheless, to obtain the total factor productivity it is necessary to assume a value *a priori* for a, which, following the neoclassical tradition, is usually obtained as the share of wages in total income.

$$q = \bar{\lambda} + (\nu a - 1)l + \nu(1-a)k \tag{3.9}$$

Similar to equation (3.7), in equation (3.9) the direct and indirect impacts of capital accumulation on productivity are explicit. Essentially, both approaches consider that if capital embodies technological advances and generates external economies, we can explain at least part of technological change by capital accumulation (if v is greater than the unity). The difference between (3.7) and (3.9) is that in (3.9) the growth of production factors (inputs) is considered to be exogenous, so it is the supply-side specification of Verdoorn's law (Rowthorn's version assuming multiple inputs rather than only employment), whilst in (3.7) output growth is the exogenous variable, which characterises the demand-side specification of Verdoorn's law.

3.3.2 Human capital augmented specification

Because Verdoorn's law is estimated for countries in different stages of development, it is important to consider that the educational level differs significantly across countries, and thus labour is not homogenous. Mankiw *et al.* (1992), for example, show that Solow's model augmented with human capital can explain more precisely countries' growth paths during the post-war period. In this view, the growth of labour in a production function must be adjusted for the schooling in order to account for the growth of human capital. In an alternative approach, Amable (1993) argues that a higher level of schooling enhances the rate of technical progress. According to him, the technical competence of labour force is essential for borrowing external technologies and for developing one's own. Hence, the level of education (not simply its growth rate) accelerates the pace of technological progress.

Therefore, in order to consider that labour differs among countries, our specification needs to control for each country's level of schooling. Assuming technological change as determined by an exogenous factor, $\bar{\lambda}$, and endogenously by output growth, such as before, but also by human capital, equation (3.4) is replaced by:

$$\lambda = \bar{\lambda} + \zeta y + \rho H \tag{3.10}$$

where H is the level of schooling, and ρ measures the impact of schooling on technological change. Thereby, if one assumes educational level as exogenous, output growth will be given by equation (3.11), instead of (3.4):

$$y = \nu[\bar{\lambda} + al + (1-a)k + \rho H] \tag{3.11}$$

Thus, we can proceed exactly as before, but instead of estimating (3.7) or (3.9), we estimate (3.12) for the demand-side version and (3.13) for the supply-side version of Verdoorn's law, as follows:

$$q = \frac{\bar{\lambda}}{a} + \frac{\nu - 1}{\nu a} y + \frac{1 - a}{a}(k - y) + \frac{\rho}{a} H \tag{3.12}$$

and

$$q = \bar{\lambda} + (\nu a - 1)l + \nu(1 - a)k + \rho H \tag{3.13}$$

3.3.3 Increasing returns to scale and technological gap

The estimation of Verdoorn's law also needs to consider that technological gap may affect productivity growth. As discussed in the first chapter, the fact that countries on a lower technological level than countries on the innovation frontier have the possibility of imitating and thus growing faster was presented by many authors based on different approaches.

In the neoclassical approach, the idea that technological gap is a relevant explanation for productivity growth is presented, for example, by Barro and Sala-i-Martin (1997). They argue that although there are costs of imitation, if they are lower than innovation costs, technological gap is relevant to explain convergence. According to Rodrick (2013), manufacturing is the sector for which imitation is the easiest, and thus specialising in manufacturing is an important source of catching-up.

Cornwall and Cornwall (2002) argue that in the literature on catching-up, the prime determinant of growth is the size of the technology gap, with the most backward economies growing faster. From a Kaldorian perspective, the authors argue that investment embodies the most advanced technologies and thus for two countries with the same investment rate, the higher the backwardness is, the higher the growth bonus is.

The importance of technological gap to explain productivity is also addressed from a Neo-Schumpeterian perspective. According to Fagerberg (1994) and Fagerberg and Verspagen (2002), neoclassical models assumes technology as a public good, and thus countries' productivity difference cannot be explained by technological gap. However, technology, rather than a global public good, is embodied in organisational structures, such as firms and regions. Hence, engaging in technological catch-up (narrowing the technology gap) is an important source of productivity growth.

Thereby, technological gap must be taken into account to estimate correctly Verdoorn's law, and thus the growth rate of an individual industry, rather than (3.11), is given by:

$$y = \nu[\bar{\lambda} + ak + (1-a)l + \rho H] + \xi G \tag{3.14}$$

where G is the technological gap, and ξ measures the impact of the technological gap on productivity growth.

Based on this, equation (3.12) can be re-specified as (3.15), which is the demand-side version of Verdoorn's law augmented for technological gap, and equation (3.13) can be re-specified as (3.16), which is its supply-side version:

$$q = \frac{\bar{\lambda}}{a} + \frac{\nu - 1}{\nu a}y + \frac{1-a}{a}(k-y) + \frac{\rho}{a}H + \frac{\xi}{a}G \tag{3.15}$$

and

$$q = \bar{\lambda} + (\nu a - 1)l + \nu(1-a)k + \rho H + \xi G \tag{3.16}$$

3.3.4 Data and sectoral aggregation

Verdoorn's law is estimated through a panel dataset for 70 countries between 1963 and 2009. Data for employees and value added are available in the UNIDO Industrial Statistics Database at the 2-digit level of the *International Standard Industrial Classification (ISIC), Rev. 3* (UNIDO-INDUSTAT2). Data for output and value added, however, are only available in nominal prices (US current prices or the various national currencies), and it is therefore necessary to deflate them before conducting the econometric tests. Although countries' price indices by sector should be used to deflate the output data, these indices are not available for most of the analysed countries. Therefore, in the absence of the ideal deflator, it is replaced with the GDP deflator for each country. These deflators are available in the Penn World Table (PWT) 7.1 (Helson *et al.*, 2012).

Another relevant issue is that data on fixed capital stocks are not available. This variable is estimated using data on gross fixed capital formation (GFCF), also available in the UNIDO database, across countries and sectors at the *ISIC 2-digit level.* Following the approach adopted in Angeriz *et al.* (2008), GFCF data is combined with approximations of probable average asset lives to estimate gross fixed capital stocks. Investment deflators, also available at PWT 7.1, for each country are applied to deflate this data.

The main issue with this data, however, is that they are not available for all countries in the same years and do not employ a single sectoral division. Therefore, before performing the estimates, each country is analysed separately with the aim of identifying those countries that will be used and those that will be discarded, as well as the sectoral aggregation that minimises the missing values. Although data on employees, output or value added and gross fixed capital formation is available between 1963 and 2009 for 38 countries, most of these are developed countries, and thus exclusively using these countries will generate a relevant bias. As a result, data on other countries has to be analysed (and in some cases calculated by interpolation) prior to conducting the econometric tests.

In terms of the sectoral aggregation, sectors originally classified at 2-digit level of the International Standard Industrial Classification (ISIC) are grouped to make it possible to extend the analysis for the longest time series. The sectors considered are the following: food, beverages and tobacco products [Food]; textiles, wearing apparel and leather products [Textiles]; wood and paper [Paper]; fuels [Fuels]; chemicals, rubber and plastic [Chemicals]; non-metallic mineral products [Non-metallic]; basic and fabricated metals [Metals]; machinery, equipment, office and computing machinery [Machinery]; electrical machinery, communication, medical, precision and optical equipment [Electrical]; motor vehicles and other transport equipment [Transport]; and furniture and other manufacturing products [Others].

Finally, these sectors are grouped according to their technological intensity and categories of demand. Regarding the technological intensity aggregation, sectors are grouped based on UNIDO (2013:205) classification for manufacturing activities. Food, Textiles, Paper, Fuels, Non-metallic, Metals and Others are grouped as low-tech manufacturing industries [LT] and Chemical, Machinery, Electrical and Transport as high-tech manufacturing industries [HT]. In terms of the categories of demand, Food, Paper, Fuels, Non-metallic and Metals are grouped as natural resource based manufacturing [NR], Textiles and Others as consumption goods chains [CG] and Machinery, Electrical and Transport as capital goods chains [KG]. Because Chemicals cannot be considered as either capital or consumption goods, this sector is not classified in any of these groups.

The analysis also uses data for level of schooling to estimate Verdoorn's law, as well as technological gap. Regarding the level of schooling, H, data on the average years of total schooling (for the population aged 15 and over) are obtained from Barro and Lee (2012) dataset.

Technological gap is defined as the complexity of countries' sectoral exports in relation to the US. Following Haussmann *et al.* (2007), a proxy for the technological complexity of sectoral exports is obtained based on the income per capita of the countries that exports similar goods. First, using the UN-COMTRADE database (SITC Rev.1), the weighted average of the income per capita of the countries that export each good is calculated, as follows:

$$PRODY_k = \sum_j \left(\frac{X_{jk}/X_j}{\sum_j X_{jk}/X_j} GDPpc_j \right) \tag{3.17}$$

where $GDPpc$ is the GDP per capita (obtained at PWT 8.0), X are exports, j stands for the country and k stands for the product.

Then, the technological complexity of exports for the sector i, $EXPY$, is calculated by the weighted average of each good $PRODY$, as follows:

$$EXPY_{ji} = \sum_k \left(\frac{X_j k}{X_j i} PRODY_k \right) \tag{3.18}$$

where k stands for all products classified inside sector i.

Finally, for each sector i, the variable technological gap, G, is defined as the ratio between the sectoral $EXPY$ of the country under consideration for the current year divided by the US's $EXPY$ for the same sector in the same year.

3.4 Verdoorn's law: different specification, different result

3.4.1 Demand-side version

As discussed in sub-section 3.2.1, different approaches can be adopted to estimate the relationship between productivity growth and output growth according to the variables assumed as exogenous. In the demand-side version, output is exogenous to the growth of inputs (capital and labour), once demand is the ultimately determinant of output growth. Thereby, in order to obtain the degree of increasing returns from this approach, equations (3.7), (3.13) and (3.16) are estimated.

The estimation technique employed here, as well as those employed in all other estimations of this work, is the System GMM estimator (Brundel and Bond, 1998). This estimator was developed based on the Arellano and Bond (1991) GMM estimator

(AB estimator), which considers two sources of persistence over time: autocorrelation due to the inclusion of lagged variables, and individual effects, controlling for the heterogeneity among individuals. In these estimators, the orthogonality between lagged variables and the disturbances generates additional instruments. The difference between AB and System GMM estimators is that the latter is estimated without exogenous regressors. Essentially, System GMM estimator uses lagged differences as instruments for equations in levels and lagged levels as instruments for equations in first difference. Hence, there is no need to find exogenous regressors as instruments for output growth.

Such as discussed in sub-section 3.2.3, because Verdoorn's law is a long-term relationship between output and productivity growth, the causal relationship between these variables should be obtained considering growth rates during periods long enough to avoid estimating the cyclical relationship between output and productivity. This approach is important to distinguish Verdoorn's law from Okun's law, which can be expressed as the short-term relationship between these variables. Thus, rather using yearly growth rates, growth rates for each seven years are calculated. Firstly, data is aggregated in periods of seven years (from 1967 to 1973, from 1974 to 1980, and so on)[69], and then growth rates between these periods are obtained.

Moreover, because output growth affects productivity through capital accumulation, it is important to consider that this impact cannot be constrained to the exact period the investment was made. As argued by Setterfield (1997), the realisation of induced technological progress through Verdoorn's law may require accumulation of specific new capital, and it enhances productivity in future periods. Hence, a lag for output growth is included, and the Verdoorn coefficient is estimated based on equations (3.19)-(3.22), as follows:

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3(k_{j,t} - y_{j,t}) + \mu_{j,t} \tag{3.19}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3(k_{j,t} - y_{j,t}) + \beta_4 H_{j,t} + \mu_{j,t} \tag{3.20}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3(k_{j,t} - y_{j,t}) + \beta_4 G_{j,t} + \mu_{j,t} \tag{3.21}$$

[69] Data from 1963 to 1966 is not used in periods aggregation because it is necessary to have at least five years to estimate the stock of capital.

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3(k_{j,t} - y_{j,t}) + \beta_4 G_{j,t} + \beta_5 H_{j,t} + \mu_{j,t} \quad (3.22)$$

where the subscript j represents each country, $\mu_(j,t)$ is the error component, which includes panel-specific error terms for years and countries.

Based on these equations, the demand-side estimated Verdoorn coefficient (the long-term impact of output growth on productivity growth) is given by:

$$b = \frac{\beta_1 + \beta_2}{1 - \delta} \quad (3.23)$$

Table 3.1 presents the Verdoorn coefficients estimated from equations (3.19)-(3.22) based on System GMM estimator for individual industries, sectoral aggregations and total manufacturing[70]. From the results, it is clear that most of the industries present a significant positive Verdoorn coefficient, which indicates that, from the demand-led perspective, they are subject to dynamic increasing returns to scale.

It is clear from the table that some sectors present Verdoorn coefficients higher than others, independently of the employed estimation. Food, Chemicals and Metals present Verdoorn coefficients higher than 0.6 with low standard deviations in all estimations, which indicates that they are highly subject to increasing returns to scale. Textiles and Electrical, on the other hand, present Verdoorn coefficients lower than 0.4 but statistically significant, which indicates that although subject to increasing returns to scale, productivity is less stimulated by output growth than in other industries. The only industry that did not present a statistically significant Verdoorn coefficient was Others, which indicates that it is subject to constant returns to scale.

Regarding the aggregate results, consumption goods is the category of demand where the Verdoorn coefficient is the lowest for all estimation (the Verdoorn coefficient of consumption goods is not statistically significant), whilst this value is the highest for capital goods and natural resource based manufacturing. The comparison between capital goods and natural resources based manufacturing shows that although the value is higher in the latter category of demand, this difference is not statistically significant at the 10% level[71]. Finally, with regards to technological intensity, both

[70] Appendix C presents the complete results.

[71] Hypothesis tests comparing these results were constructed based on the estimated coefficient and standard deviations presented in Table 3.1. The t-statistic comparing capital goods and natural resource based manufacturing for equations (3.19)-(3.22) are, respectively, 0.91, 0.79, 0.82 and 0.79,

Table 3.1: Verdoorn coefficient (demand-side specification estimation), by industries and aggregates

	No controls	Schooling	Gap	School.+Gap
Food	0.674***	0.695***	0.766***	0.768***
	(0.136)	(0.139)	(0.137)	(0.134)
Textiles	0.334**	0.369**	0.369***	0.408***
	(0.140)	(0.145)	(0.132)	(0.128)
Paper	0.466***	0.471***	0.47***	0.474***
	(0.062)	(0.064)	(0.081)	(0.083)
Fuels	1.027**	1.027**	1.025**	1.025**
	(0.466)	(0.474)	(0.451)	(0.435)
Chemicals	0.687***	0.706***	0.696***	0.714***
	(0.110)	(0.095)	(0.105)	(0.103)
Non-metallic	0.579***	0.566***	0.555***	0.532***
	(0.193)	(0.212)	(0.204)	(0.202)
Metals	0.670***	0.696***	0.673***	0.686***
	(0.136)	(0.138)	(0.120)	(0.131)
Machinery	0.483***	0.492***	0.483***	0.491***
	(0.132)	(0.136)	(0.136)	(0.137)
Electrical	0.338**	0.350**	0.371***	0.366***
	(0.158)	(0.157)	(0.136)	(0.138)
Transport	0.467***	0.474***	0.484***	0.489***
	(0.12)	(0.117)	(0.124)	(0.121)
Others	0.208	0.226	0.209	0.210
	(0.372)	(0.360)	(0.375)	(0.361)
Consumption Goods (CG)	-0.089	0.020	0.163	0.233
	(0.138)	(0.14)	(0.15)	(0.143)
Capital Goods (KG)	0.473***	0.49***	0.484***	0.496***
	(0.149)	(0.156)	(0.176)	(0.174)
NR based manuf. (NR)	0.645***	0.642***	0.661***	0.662***
	(0.116)	(0.113)	(0.126)	(0.12)
Low-tech manuf. (LT)	0.462**	0.478**	0.466**	0.482**
	(0.209)	(0.197)	(0.227)	(0.208)
High-tech manuf. (HT)	0.519***	0.493***	0.503***	0.502***
	(0.173)	(0.149)	(0.171)	(0.168)
Manufacturing	0.527***	0.571***	0.548***	0.572***
	(0.162)	(0.159)	(0.152)	(0.153)

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates.
Controls - Schooling: controlled by human capital; Gap: controlled by technological gap; School.+Gap: controlled by human capital and technological gap.
*: significant at the 10% level; **: significant at the 5% level; ***: significant at the 1% level.
See Appendix C for complete results.

indicating that the null hypothesis that they present different Verdoorn coefficients cannot be rejected at the 10% level.

high- and low-tech products presents Verdoorn coefficients statistically higher than zero, indicating that they are subject to dynamic increasing returns. Moreover, even though the value is higher for high-tech than low-tech products, the difference between these categories is not statically significant different at the 10% level[72]. Thereby, one cannot conclude that they have different degrees of increasing returns to scale.

Another interesting issue that emerges from these results is that the degree of increasing returns is not necessarily higher at the individual industrial level than in the manufacturing level. As discussed in Chapter 1, according to Young, increasing returns is a macroeconomic phenomenon. The author argues that Verdoorn's law is not restricted to firms or industries, but it is derived from inter-industry division of labour and specialisation, and thus increasing returns to scale have to be found in the total manufacturing level. However, contrary to these arguments, some studies, such as McCombie (1985) and Angeriz *et al.* (2009), have found significant Verdoorn coefficients at the industrial level[73]. These results corroborate the Marshallian notion of increasing returns to scale, which stresses the importance of localisation economies (resulting from the geographical concentration of firms in the same industry). According to this view, geographical clustering of industrial activities facilitates research and innovation in a specific industry, the exchange of ideas and knowledge between firms, as well as stimulating the concentration of a pool of workers with specific skills in this country or region.

As can be seen from Table 3.1, the Verdoorn coefficient in Manufacturing is higher than some sectors, such as Textiles, Electrical and Others, but it is lower than the one obtained for other sectors, such as Food, Chemicals and Metals. Hence, both approaches for the existence of increasing returns to scale can be considered valid: the Marshallian notion of localisation economies is important to explain the higher Verdoorn coefficient obtained in Food, Chemicals and Metals, whilst Young's notion of increasing returns as a macroeconomic phenomenon is important to explain the high value obtained for Manufacturing.

It is important to note, however, that, even considering only the Marshallian notion of localisation economies to explain increasing returns to scale, it does not mean that cumulative causation cannot take place in the Kaldorian sense. Instead, if the sectors that present the highest degree of increasing returns are the same as those that

[72]The t-statistic comparing high-tech and low-tech products for equations (3.17)-(3.20) are, respectively, 0.21, 0.06, 0.13 and 0.07.

[73]The authors found higher increasing returns for all sub-sectors than for manufacturing, with the only exception of Textiles.

present the highest income elasticities, such as presented by Araujo (2013) for a closed economy and Fiorillo (2001) for an export-led economy, specialisation in these sectors will reinforce a cumulative process of increasing growth rates.

3.4.2 Supply-side version

The assumption that factor inputs are exogenous to output growth implies that long-term economic growth is not determined by demand growth, such as stressed by Kaldor (1966; 1970). Instead, it is determined by the capability of a country to increase savings by reducing consumption or by the allocation of this saving for activities that present the highest positive externalities, such as R&D and education. This notion, as discussed in first chapter, is at the root of neoclassical and “endogenous” growth models. The estimation of increasing returns assuming factor inputs as exogenous (rather than endogenous, such as in demand-side version) must consider these factors as regressors instead of output growth, such as presented by Kaldor-Rowthorn controversy. Thereby, instead of estimating equations (3.7), (3.13) and (3.16), equations (3.9), (3.14) and (3.17) are estimated to obtain the degree of increasing returns based on the supply-side approach.

Similar to the estimation for the demand-side approach, it is necessary to consider that the relation between productivity growth and output growth is a long-term relationship. Hence, the same method to calculate seven years growth rates rather than yearly growth rates is applied. Moreover, lags are also considered in the estimation to account for the impact of investments in former periods. The following equations are thus estimated through a System GMM:

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 l_{j,t} + \beta_2 l_{j,t-1} + \beta_3 k_{j,t} + \beta_4 k_{j,t-1} + \mu_{j,t} \tag{3.24}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 l_{j,t} + \beta_2 l_{j,t-1} + \beta_3 k_{j,t} + \beta_4 k_{j,t-1} + \beta_5 H_{j,t} + \mu_{j,t} \tag{3.25}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 l_{j,t} + \beta_2 l_{j,t-1} + \beta_3 k_{j,t} + \beta_4 k_{j,t-1} + \beta_5 G_{j,t} + \mu_{j,t} \tag{3.26}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 l_{j,t} + \beta_2 l_{j,t-1} + \beta_3 k_{j,t} + \beta_4 k_{j,t-1} + \beta_5 G_{j,t} + \beta_6 H_{j,t} + \mu_{j,t} \tag{3.27}$$

where the subscript j represents each country, $\mu_{j,t}$ is the error component, which includes panel-specific error terms for years and countries.

From these estimations, the Verdoorn coefficient is obtained as follows:

$$b = \frac{\beta_1 + \beta_2 + \beta_3 + \beta_4}{(1-\delta)(1+\beta_1+\beta_2)} \tag{3.28}$$

Table 3.2 presents the supply-side Verdoorn coefficient (Rowthorn's specification considering multiple factors of production) for individual industries, sectoral aggregates and total manufacturing. From these results, it is clear that industries are not subject to increasing returns. In all specifications for all sectors, an increase in factor inputs has an insignificant impact on labour productivity (at the 5% level), which means that accumulation of capital and labour increases output but at constant rates.

These results corroborate the findings of Angeriz *et al.* (2008) for total manufacturing and the findings of Angeriz *et al.* (2009) for manufacturing industries. In their works, they show that in the demand-side specification (where it is assumed that capital and labour responds endogenously to the growth of demand) manufacturing and its industries are subject to increasing returns, whilst in the supply-side specification (where factor inputs are exogenous to demand growth) they are not. Here, these findings are extended based on countries in different stages of development, but the results remain the same. Although some industries, such as Non-metallic, Metals and Machinery present higher degrees of increasing returns, the values are never significant at the 5% level, which indicates that, independently of the industry, if one assumes that labour and capital are not induced by demand growth, neither manufacturing nor its industries are subject to increasing returns to scale.

The comparison between the demand-side and supply-side specification results shows that assumptions *a priori* about the determinants of investment and labour mobility are very relevant to explain cumulative causation and countries' growth rates divergence. The assumption behind the neoclassical and endogenous growth models is that investment is determined by savings rather than by demand. Based on this assumption, one can conclude that productivity is not induced by output growth once industries are not subject to increasing returns. On the other hand, the assumption behind the Kaldorian approach is that a faster growth of demand induces investment and thus production factors are endogenous to demand. Based on this view, one can conclude that productivity responds positively to output growth, once sectors are

Table 3.2: Verdoorn coefficient (supply-side specification estimation), by industries and aggregates

	No controls	Schooling	Gap	School.+Gap
Food	0.115	0.072	0.136	0.115
	(0.279)	(0.287)	(0.302)	(0.302)
Textiles	-0.157	-0.152	-0.085	-0.042
	(0.796)	(0.741)	(0.598)	(0.591)
Paper	0.085	0.079	0.059	0.054
	(0.278)	(0.287)	(0.286)	(0.294)
Fuels	5.381	8.853	3.479	3.988
	(5.053)	(9.222)	(2.923)	(3.586)
Chemicals	0.022	0.062	0.170	0.174
	(0.442)	(0.474)	(0.496)	(0.495)
Non-metallic	0.337	0.293	0.224	0.278
	(0.416)	(0.55)	(0.765)	(0.736)
Metals	-0.613	-0.472	-0.413	-0.377
	(0.759)	(0.506)	(0.507)	(0.472)
Machinery	0.094	0.094	0.140	0.135
	(0.348)	(0.353)	(0.326)	(0.326)
Electrical	-0.172	-0.244	-0.116	-0.155
	(0.513)	(0.541)	(0.356)	(0.359)
Transport	-0.414*	-0.385	-0.309	-0.307
	(0.244)	(0.244)	(0.286)	(0.284)
Others	-0.633	-0.664	-0.635	-0.744
	(0.86)	(0.884)	(0.886)	(0.94)
Consumption Goods (CG)	-0.502	-0.557	-0.327	-0.344
	(0.471)	(0.471)	(0.467)	(0.475)
Capital Goods (KG)	-0.490	-0.473	-0.022	-0.026
	(0.604)	(0.608)	(0.442)	(0.441)
NR based manuf. (NR)	0.075	0.018	-0.088	-0.077
	(0.449)	(0.372)	(0.425)	(0.421)
Low-tech manuf. (LT)	-0.272	-0.251	-0.437	-0.419
	(0.420)	(0.336)	(0.391)	(0.388)
High-tech manuf. (HT)	0.045	0.042	0.145	0.147
	(0.451)	(0.446)	(0.403)	(0.398)
Manufacturing	-0.356	-0.352	-0.326	-0.289
	(1.035)	(1.02)	(1.015)	(0.988)

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates.

Controls - Schooling: controlled by human capital; Gap: controlled by technological gap; School.+Gap: controlled by human capital and technological gap.

*: significant at the 10% level; **: significant at the 5% level; ***: significant at the 1% level.

See Appendix C for complete results.

subject to increasing returns to scale.

Therefore, once it is assumed that growth is demand-driven rather than supply constrained, one can infer that technological progress is induced by output growth, and thus high and sustained growth rates depends on the specialisation in those sectors with the highest degree of increasing returns to scale, such as natural resources and capital goods.

3.5 Verdoorn's law according to countries' stage of development

One of the basic assumptions behind the estimation of the Verdoorn's law through panel models using countries as the cross-section is that the Verdoorn coefficient does not vary according to countries' characteristics. The Verdoorn coefficient is a parameter that determines the slope of the curve that relates output growth, on one axis, and productivity growth, on the other.

However, there are enough theoretical reasons for believing that the degree of increasing returns is not constant for countries in different stages of development, especially when it is estimated at the individual industry level. Skilled workers, for example, might be more important for some activities than others according to countries' stage of development. One could expect that more complex activities, which demand more qualified workers, present higher increasing returns to scale in more advanced economies than in developing countries. On the other hand, a greater pool of less qualified workers is important for labour-intensive activities, once the activity growth would not be constrained by labour availability. Hence, these activities might have higher increasing returns in less developed economies.

Taking advantage of having a dataset with countries in different stages of development, output growth can be interacted with countries' income per capita in order to obtain the Verdoorn coefficient according to countries' stage of development. Based on this interaction, Verdoorn's law is estimated allowing for changes in the coefficient according to countries' income per capita (as a proxy for their stage of development), through heterogeneous regressions[74]. This estimation may bring some important issues for the debate on the importance of sectoral structure for countries development,

[74]See Agung (2014:278-285) for a detailed presentation of this method and prior applications. Woodridge (2002:170-171) presents an example of this method for a panel data model.

once different industries can present different degrees of increasing returns according to countries' income.

Instead of estimating equations (3.19)-(3.22), a modified version of the demand approach for Verdoorn's law is estimated as follows:

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3 y_{j,t} \ln(GDPpc_{j,\bar{t}}) + \\ + \beta_4 y_{j,t-1} \ln(GDPpc_{j,\bar{t}}) + \beta_5 (k_{j,t} - y_{j,t}) + \mu_{j,t} \tag{3.29}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3 y_{j,t} \ln(GDPpc_{j,\bar{t}}) + \\ + \beta_3 y_{j,t-1} \ln(GDPpc_{j,\bar{t}}) + \beta_5 (k_{j,t} - y_{j,t}) + \beta_6 H_{j,t} + \mu_{j,t} \tag{3.30}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3 y_{j,t} \ln(GDPpc_{j,\bar{t}}) + \\ + \beta_4 y_{j,t-1} \ln(GDPpc_{j,\bar{t}}) + \beta_5 (k_{j,t} - y_{j,t}) + \beta_6 G_{j,t} + \mu_{j,t} \tag{3.31}$$

$$q_{j,t} = \beta_0 + \delta q_{j,t-1} + \beta_1 y_{j,t} + \beta_2 y_{j,t-1} + \beta_3 y_{j,t} \ln(GDPpc_{j,\bar{t}}) + \\ + \beta_4 y_{j,t-1} \ln(GDPpc_{j,\bar{t}}) + \beta_5 (k_{j,t} - y_{j,t}) + \beta_6 G_{j,t} + \beta_7 H_{j,t} + \mu_{j,t} \tag{3.32}$$

where $GDPpc_{j,\hat{t}}$ is country j's GDP per capita in a fixed period (here, 2005).

The Verdoorn coefficient provided by these estimations is not obtained directly by β_1 and β_2, such as in (3.23). Instead, it is obtained by the interaction of output with countries' income, which means that it is not a parameter, but a function of countries' income. Thus, rather than one value, an estimation for the Verdoorn coefficient that depends on countries' GDP per capita is obtained, as follows:

$$b = \frac{\beta_1 + \beta_2 + (\beta_3 + \beta_4) \ln(GDPpc_{j,\bar{t}})}{1 - \delta} \tag{3.33}$$

3.5.1 Verdoorn's law at the industry level

Tables 3.3-3.6 and Figures 3.1-3.4 presents the results for the Verdoorn coefficient according to countries' GDP per capita estimated based System GMM. As can be seen in Table 3.3, which presents the results for estimations that do not control the technological gap (equations 3.26 and 3.27), most sectors have positive Verdoorn coefficients independent of country's income per capita. The only case in which this value is negative is Textiles for high-income countries, indicating diminishing returns to scale. In all other cases, the Verdoorn coefficient indicates that production is subject to dynamic increasing returns to scale.

Table 3.3: Verdoorn coefficient according to countries' income level (not controlling for technological gap), by industries

	No controls			Controls: Schooling		
	Low-income	Middle-income	High-income	Low-income	Middle-income	High-income
Food	0.75	0.65	0.55	0.81	0.67	0.53
Textiles	0.63	0.12	-0.38	0.63	0.21	-0.22
Paper	0.46	0.45	0.44	0.47	0.45	0.44
Fuels	1.10	0.93	0.76	1.10	0.93	0.76
Chemicals	0.73	0.73	0.72	0.82	0.76	0.69
Non-metallic	0.63	0.58	0.53	0.65	0.57	0.48
Metals	0.75	0.68	0.60	0.85	0.71	0.56
Machinery	0.59	0.48	0.37	0.64	0.51	0.37
Electrical	0.24	0.28	0.31	0.27	0.28	0.30
Transport	0.54	0.42	0.30	0.56	0.43	0.30
Others	0.31	0.28	0.24	0.36	0.29	0.22
Manufacturing	0.66	0.49	0.32	0.73	0.53	0.32

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates. Low-income: GDPpc = US$ 2,500 in 2005; Middle-income: GDPpc = US$ 10,000 in 2005; High-income: GDPpc = US$ 40,000 in 2005.

See Appendix C for complete results and significance.

From Table 3.3 is also possible to verify that for the majority of sectors, the Verdoorn coefficient is higher for low-income countries than for high-income countries. The fourth and the last column present the impact of the increase in countries' income on the Verdoorn coefficient, and it shows that the coefficient drops as countries reach higher levels of development. Besides Textiles, which has negative values for high-income countries, this drop in the Verdoorn coefficient is also verified in Food, Fuels, Metals, Machinery and Transport, as well as for total manufacturing. In Electrical, on the other hand, the Verdoorn coefficient increases as countries' GDP per capita increases. Not controlling for level of schooling, the long-term impact of output growth on productivity for Electrical is 0.24 for low-income countries (US$ 2,500 per capita), and 0.31 for high-income countries (US$ 40,000 per capita).

Table 3.4 presents the estimation for the Verdoorn coefficient estimated through equations (3.28) and (3.29), which controls for technological gap. These results do not differ substantially from those presented in Table 3.2. Although technological gap can partially explain productivity growth, such as discussed in the Subsection 3.3.3, it does not interfere on the estimation of the degree of increasing returns at the individual industry level. The main difference between these results is that rather than positively related to countries' GDP per capita, the Verdoorn coefficient in Electrical is constant when controlled by the gap. Moreover, the Verdoorn coefficient of Non-metallic is positively related to countries' GDP per capita when the impact of technological gap is used as control.

Table 3.4: Verdoorn coefficient according to countries' income level (controlling for technological gap) , by industries

	Controls: Gap			Controls: Schooling and Gap		
	Low-income	Middle-income	High-income	Low-income	Middle-income	High-income
Food	0.87	0.72	0.56	0.88	0.72	0.56
Textiles	0.66	0.17	-0.32	0.65	0.24	-0.16
Paper	0.52	0.48	0.45	0.54	0.49	0.44
Fuels	1.07	0.92	0.78	1.08	0.92	0.77
Chemicals	0.81	0.75	0.69	0.84	0.77	0.69
Non-metallic	0.57	0.61	0.65	0.53	0.57	0.61
Metals	0.79	0.67	0.55	0.85	0.70	0.54
Machinery	0.58	0.48	0.39	0.62	0.50	0.38
Electrical	0.32	0.32	0.32	0.31	0.31	0.32
Transport	0.61	0.44	0.28	0.62	0.45	0.29
Others	0.34	0.27	0.19	0.36	0.28	0.20
Manufacturing	0.72	0.51	0.30	0.73	0.53	0.33

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates. Low-income: GDPpc = US$ 2,500 in 2005; Middle-income: GDPpc = US$ 10,000 in 2005; High-income: GDPpc = US$ 40,000 in 2005.

See Appendix C for complete results and significance.

This analysis shows that almost every sector presents high degrees of increasing returns for countries in the early stages of development, but in most sectors, as countries' incomes grow, the Verdoorn coefficient decreases. Thus, only a few sectors present high Verdoorn coefficients for countries in the later stages of development.

3.5.2 Technologic Intensity

One of the main sources of dynamic increasing returns at the industry level is technological search and knowledge diffusion. According to Fagiolo and Dosi (2003:239), "technological advances are endogenously generated through resource-expansive search undertaken by multiple agents". Thereby, one can expect a higher degree of increasing returns in sectors with higher technological intensity, once expenses in research and technological diffusion are the main drivers of productivity growth in these sectors. Moreover, it is also plausible to expect higher a Verdoorn coefficient as countries' incomes increase, once the level of GDP per capita is strictly related to expenditures on R&D and innovation activities.

In order to evaluate the degree of increasing returns among sectors with different technologic intensity, industries were aggregated according to technological intensity into high- and low-tech manufacturing. The same methodology used before to estimate the Verdoorn coefficient according to countries' GDP per capita is applied here and the results are present in Table 3.5 and Figures 3.1-3.2.

Table 3.5: Verdoorn coefficient according to countries' income level (not controlling for technological gap), by technological intensity

	No controls			Controls: Schooling		
	Low-income	Middle-income	High-income	Low-income	Middle-income	High-income
Low-tech	0.49	0.45	0.41	0.65	0.50	0.35
High-tech	0.49	0.53	0.58	0.53	0.55	0.57
Manufacturing	0.72	0.51	0.30	0.73	0.53	0.33

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates. Low-income: GDPpc = US$ 2,500 in 2005; Middle-income: GDPpc = US$ 10,000 in 2005; High-income: GDPpc = US$ 40,000 in 2005.
See Appendix C for complete results and significance.

The results of the first estimation (equation 3.26) show that low-tech industries present the same Verdoorn coefficient as high-tech for low levels of income (US$ 2,500 per capita). However, as GDP per capita increases the Verdoorn coefficient of high-tech industries increases and the Verdoorn coefficient of low-tech industries decreases. Hence, the degree of increasing returns is higher in high-tech than in low-tech for middle- and high-income countries. It means that specialisation in low-tech industries increases the productivity of the sector itself only for low-income countries. Conversely, for middle- and for high-income countries, industries with high technological intensity are those capable to boost productivity growth the most, once they present the highest Verdoorn coefficient.

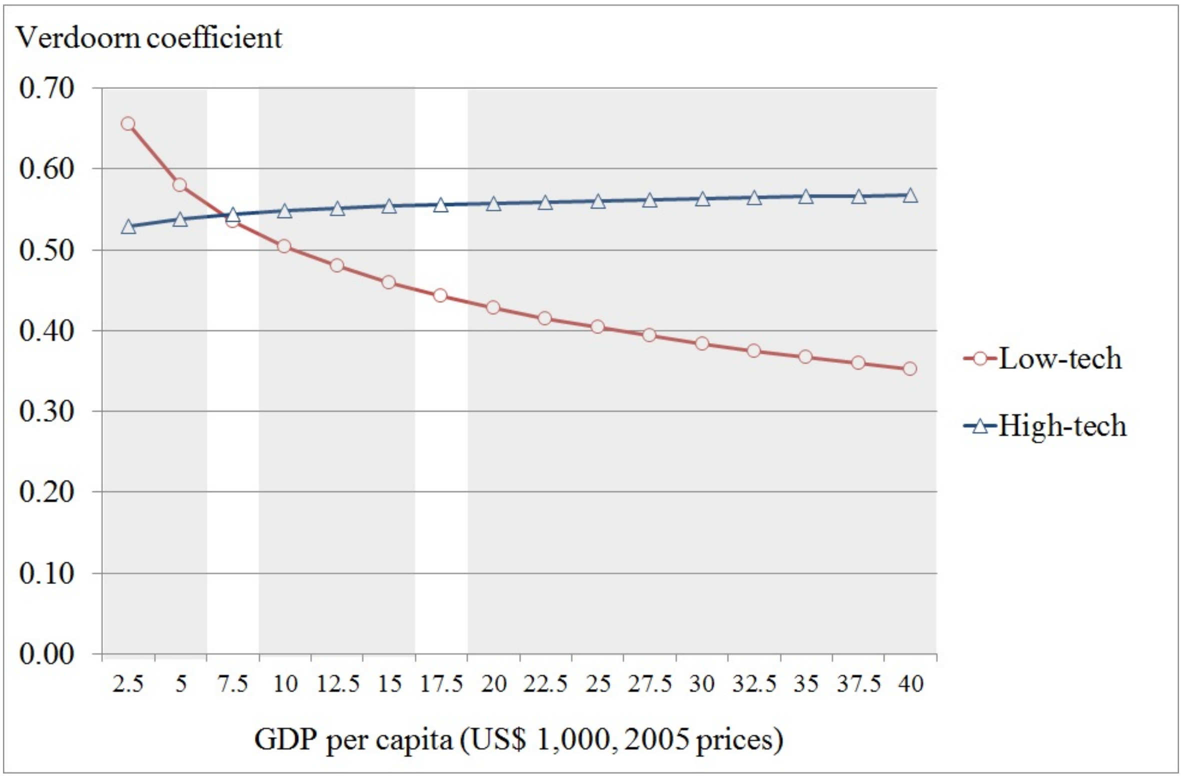
The results do not change substantially when estimation controls for the level of schooling (estimation based on equation 3.27). The main difference is that low-tech industries present the highest degree of increasing returns for low-income countries, which indicates that specialisation in low-tech manufacturing is an important source of scale economies for those countries in the early stages of development. However, as countries' incomes grow, it is important to promote structural changes towards industries with higher technologic intensity in order to increase productivity, once the Verdoorn coefficient in low-tech industries drops from 0.65 in low-income countries (US$ 2,500 per capita) to 0.35 in countries where GDP per capita is high (US$ 40,000 per capita).

The results for the Verdoorn coefficient controlled for technological gap also show the importance of promoting high-tech sectors to benefit from scale economies when countries reach high stages of development. As can be seen from Figure 3.1, despite presenting the highest Verdoorn coefficient for low-income countries, low-tech manufacturing industries present the lowest Verdoorn coefficient for medium- and high-income countries. The faster growth of output affects positively productivity growth by a coefficient of 0.6 (which indicates that a faster growth of output by 1.0 p.p. increases productivity growth by 0.6 p.p.) for countries that income per capita is US$ 2,500, but this impact drops to around 0.4 in the case of high-income countries. In high-tech sectors, on the other hand, the Verdoorn coefficient is greater than 0.5 independent of countries' stages of development.

The estimation of Verdoorn coefficient controlling for both technological gap and level of schooling corroborates these findings. As presented in Figure 3.2, specialisation in low-tech industries might benefit countries in the early stages of development. However, to take advantage of this important source of productivity growth, countries in advanced stages of development need to migrate to high-tech industries, once these industries present the highest Verdoorn coefficients.

The main difference between the results controlling for the level of schooling is that the Verdoorn coefficient for low-tech sectors is even higher for countries in the early stages of development and even lower for advanced countries. The coefficient for low-tech industries is around 0.7 for countries that income is US$ 2,500, and it falls to less than 0.35 for countries that income is greater than US$ 40,000. Thereby, the

Figure 3.1: Verdoorn coefficient according to countries' income level (controlling for technological gap), by technological intensity

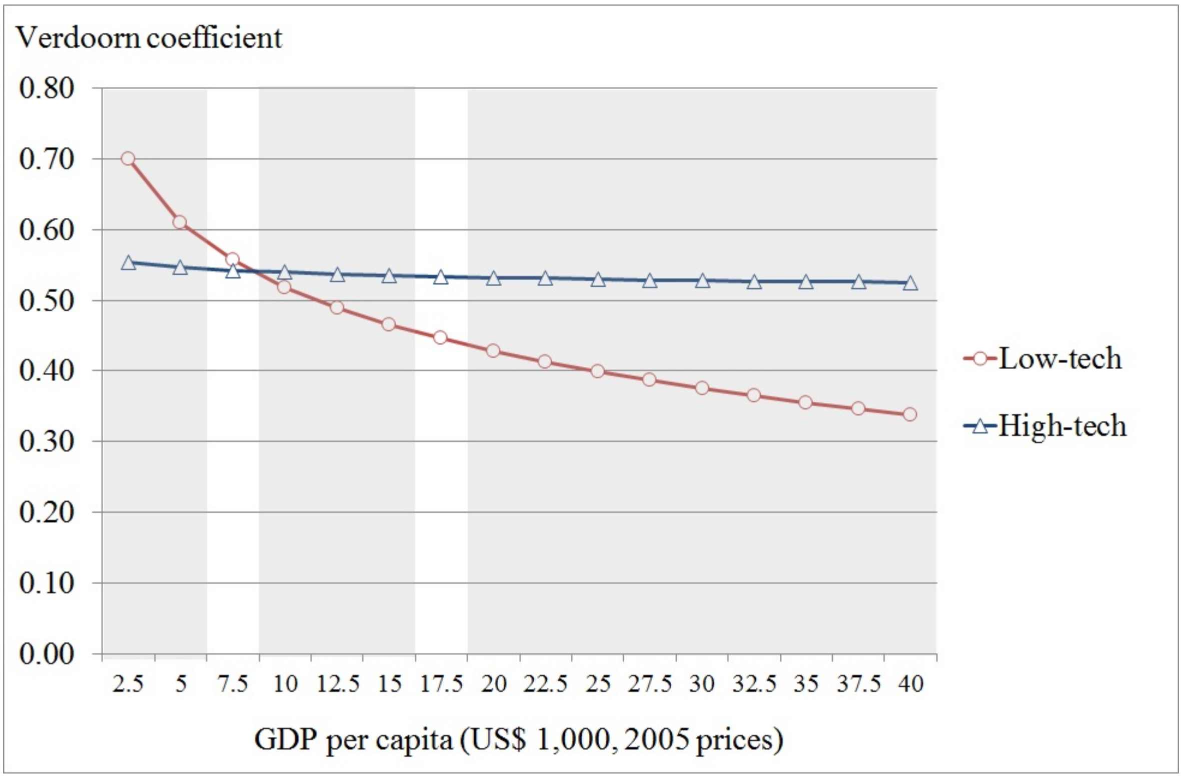


estimation controlling for technological gap and level of schooling clearly shows that countries must promote high-tech industries when they reach high levels of income, otherwise they will not benefit from dynamic increasing returns to scale.

3.5.3 Categories of demand

An alternative approach that can be adopted to understand the differences in the degree of dynamic increasing returns among industries is based on the categories of demand. Lundvall (1988) argued that capital goods industries, when associated with users, are responsible for most of innovations in the economy, and they are central in the process of technological diffusion. Therefore, one can argue that productivity growth in capital goods industries is mainly driven by the increase of production in the industry itself (when it is associated with users), whilst the increase of productivity in consumption goods is mainly driven by the increase of production in other industries in the economy.

Figure 3.2: Verdoorn coefficient according to countries' income level (controlling for technological gap and human capital), by technological intensity



Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1963 to 2009 (unbalanced) based on seven years growth rates.

Furthermore, as stressed by Kaldor (1966, 1967), capital investment is an important source of demand for countries in the most advanced stages of development, because manufacturing generates demand for its own products. He argues that countries have to promote the import-substitution and exports of capital goods, because this sector will provide the goods on which capital expenditure is spent. Thus, the very establishment of a capital goods sector is an important source of increasing returns to scale from the demand side. Productivity growth will extend this sector's market size, and thus this sector will display a self-generating demand for capital goods, which is a central element of cumulative causation. On the other hand, if this sector is not internalised, although increases in output can increase productivity, it will not be able to promote an increase in its market, and thus it will be a constraint for the continuity of a cumulative process.

In order to estimate the degree of dynamic increasing returns according to categories of demand, industries are grouped into three categories: natural resource based manufacturing [NR], consumption goods chains [CG] and capital goods chains [KG].

Verdoorn's law is estimated based on the same methodology employed before. Table 3.4 and Figures 3.3-3.4 present the results for each of these categories according to countries' income per capita based on an estimation of equations (3.26)-(3.29).

As presented in Table 3.4, production of consumption goods boosts productivity of the industry itself only for low-income countries. As countries reach high stages of development, the Verdoorn coefficient in these industries drop and output growth stops stimulating productivity growth (for middle- and high-income countries this value is negative). The production of capital goods and natural resource based manufacturing, on the other hand, is an important source of dynamic increasing returns independent of countries' stages of development.

Table 3.6: Verdoorn coefficient according to countries' income level (not controlling for technological gap), by categories of demand

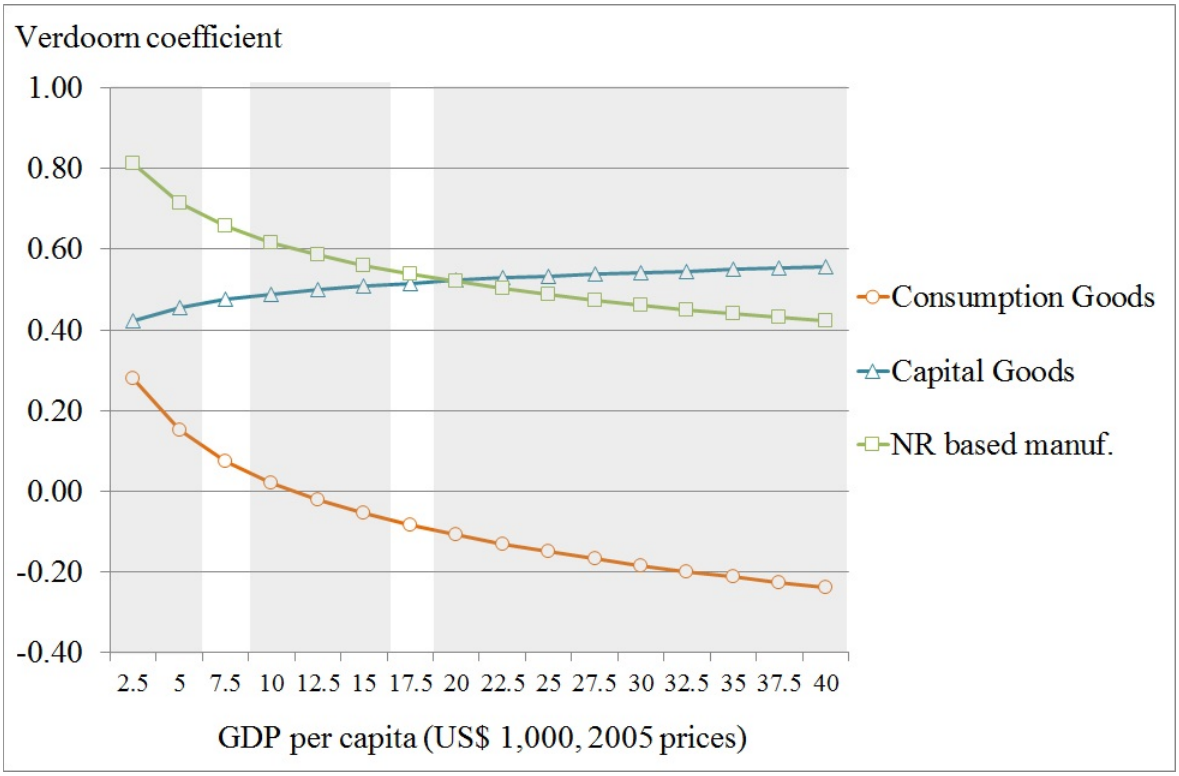
	No controls			Controls: Schooling		
	Low-income	Middle-income	High-income	Low-income	Middle-income	High-income
Consumption Goods	0.12	-0.25	-0.61	0.28	-0.04	-0.35
Capital Goods	0.41	0.48	0.55	0.44	0.49	0.53
NR based manuf.	0.72	0.58	0.43	0.82	0.61	0.40
Manufacturing	0.72	0.51	0.30	0.73	0.53	0.33

Verdoorn coefficient estimated through System GMM for 70 countries and data ranging from 1967 to 2009 (unbalanced) based on seven years growth rates. Low-income: GDPpc = US$ 2,500 in 2005; Middle-income: GDPpc = US$ 10,000 in 2005; High-income: GDPpc = US$ 40,000 in 2005. See Appendix C for complete results and significance.

Different from the results obtained for the Verdoorn coefficient at the individual industry level, the relationship between the Verdoorn coefficient and countries' GDP per capita is positive only in the case of capital goods. The summation of β_3 and β_4 in capital goods is equal to 0.05 in the estimation based on equation (3.26) and it is 0.03 in the estimation controlling for the level of schooling, which means that the higher countries' income per capita, the higher is the benefit of specialising in capital goods. These results suggest that productivity growth in individual capital good industries is related to a faster growth of other capital goods industries, especially for middle- and high-income countries. Essentially, if a specific capital good industry, such as Machinery or Transport, grows alone, the impact on productivity growth is lower than if all these industries grow together. This fact corroborates Young's notion of increasing returns to scale in the macroeconomic level, and it shows that it is especially relevant for countries in advanced stages of development.

In the estimation that controls for technological gap, the Verdoorn coefficient of consumption goods is higher, even though it is still lower than the coefficient of capital goods and natural resource based manufacturing. As can be seen from Figure 3.3, the impact of a faster output growth on productivity growth is similar for consumption and capital goods for low-income countries. However, the Verdoorn coefficient of consumption goods becomes negative for high-income countries, indicating that they are subject to diminishing returns to scale.

Figure 3.3: Verdoorn coefficient according to countries' income level (controlling for technological gap), by categories of demand

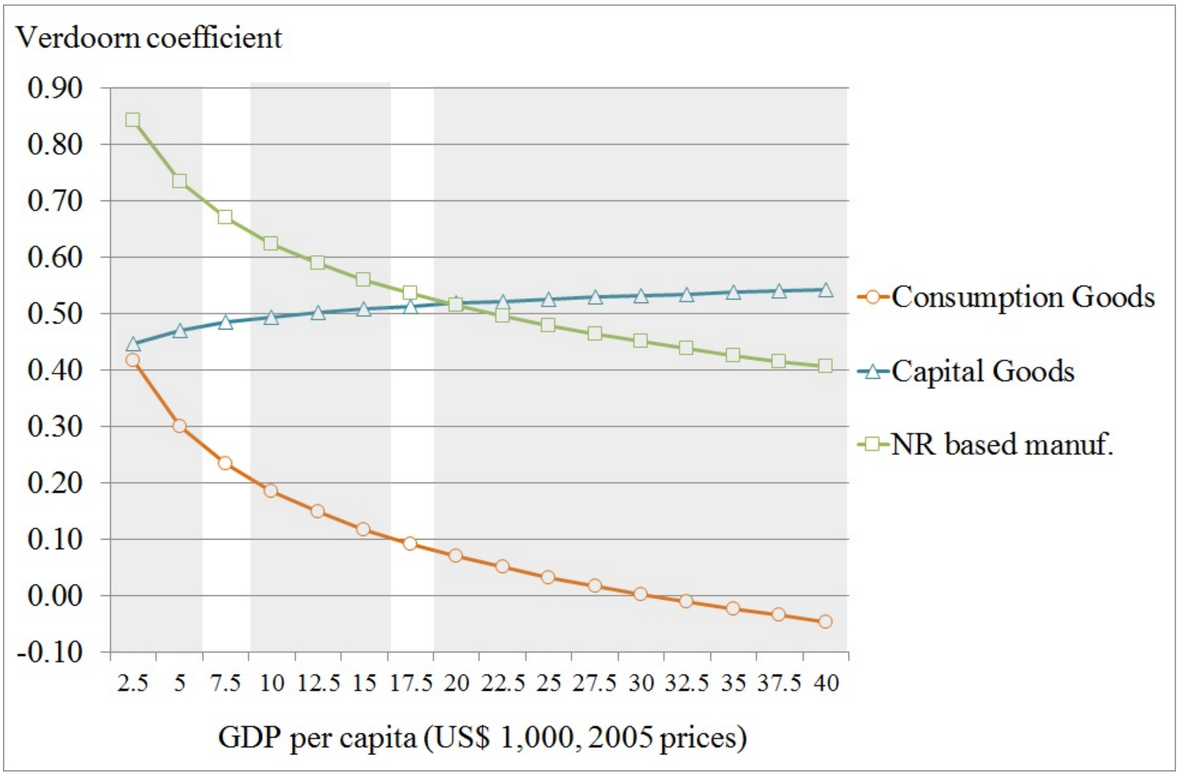


Specialisation in natural resource based manufacturing and capital goods, on the other hand, is an important source of productivity growth independent of countries' stage of development. Even though the Verdoorn coefficient of natural resource based manufacturing is higher than the coefficient of capital goods for low- and middle-income countries and the coefficient of capital goods is the highest for high-income countries, both categories present coefficients greater than 0.4 for countries in all stages of development.

When the estimation is controlled by the level of schooling, results are similar to those presented before, as presented in Figure 3.4. Although natural resources present high degree of increasing returns for low-income countries, as countries' income per capita increases, the importance of these industries reduces relatively to capital goods.

The main difference from this estimation and the one not controlling for the level of schooling is that consumption goods present high increasing returns for low-income countries, and it is similar to the coefficient found to capital goods. However, the Verdoorn coefficient of consumption goods falls from around 0.4 for low-income countries to close to zero for high-income countries, whilst capital goods' coefficient increases from 0.45 to more than 0.5. Consequently, even though the impact of faster output growth on productivity is similar in capital and consumption goods for low-income countries, for middle-income countries capital goods, the Verdoorn coefficient is significantly greater than coefficient for consumption goods, and, for high-income countries, it is greater than the coefficient of natural resource based manufacturing.

Figure 3.4: Verdoorn coefficient according to countries' income level (controlling for technological gap and human capital), by categories of demand



3.6 Concluding remarks

There is an important debate on economic theory about why some developing countries were able to achieve sustained high-growth rates and their income per capita have converged towards developed ones, and why others were not. This chapter tried to assess this issue from a Kaldorian approach, which stress the importance of increasing returns to scale in some sectors. More specifically, the degree of increasing returns was estimated according to countries' stages of development through heterogeneous regressions.

The first result corroborates the findings of previous studies, which has stressed that increasing returns to scale is a demand-led (rather than supply constrained) phenomenon. By estimating Verdoorn's law assuming demand as exogenous, significant results were found; whilst the results obtained through the supply-side version of this law suggest that manufacturing and its industries are not subject to increasing returns. In this sense, if one considers a priori a Kaldorian perspective, in which capital accumulation and labour are induced by growth in demand, manufacturing industries are subject to increasing returns to scale, which means that productivity growth is demand-driven. Conversely, if one assumes that factor inputs are exogenous in respect to demand in the long run, such as in the neoclassical or endogenous growth models, manufacturing industries are subject to constant returns to scale, and thus productivity growth is not induced by output growth, such as predicted by Verdoorn's law.

Similar to the findings of previous studies, which have found that individual industries present high increasing returns, this chapter has presented evidence that there are many sectors where the degree of increasing returns is lower than for total manufacturing. This result suggests that although localisation economies is an important explanation for the endogeneity of technological progress, once total manufacturing presents a high Verdoorn coefficient, dynamic increasing returns to scale is also a macroeconomic phenomenon, such as suggested by Young.

Furthermore, it was found that the Verdoorn coefficient in most of manufacturing individual industries drops as countries' GDP per capita increases, suggesting that countries have to specialise in manufacturing to take advantage of dynamic increasing returns especially in the early stages of development. In contrast to these findings, when sectors are grouped according to technological intensity and categories of demand, it was found that countries in the early stages of development benefit from specialising in low-tech manufacturing and consumption goods, because they present relatively higher Verdoorn coefficient for low-income countries. However, as countries reach higher stages of development, it is important to promote structural changes in favour of high-tech manufacturing sectors and capital goods. Although these industries present relatively low dynamic increasing returns for low-income countries, their degree of increasing returns is the highest for high-income countries. Because technological search and knowledge diffusion are more important in these industries, and countries in higher stages of development have better conditions to invest on these factors, they can benefit the most by specialising in these industries.

These findings can explain why industrial policies that promote changes from low-tech manufacturing and consumption goods production to high-tech manufacturing and capital goods industries are important to reduce countries' income gap. These results are especially important for countries in the intermediate stages of development. It shows that promoting manufacturing is important for countries in the early stages of development, especially promoting labour-intensive activities, such as Textiles. However, when a country reaches an intermediate stage, specialising in manufacturing is not enough; it is necessary to promote structural changes towards capital goods industries and industries with high technological intensity to boost productivity growth.

Chapter 4

Cumulative causation in open economies: investigating the impact of structural changes

4.1 Introduction

The process of structural change is crucial to understand countries' long-term economic growth. Although there is no doubt that production and trade structures of economies change over time, and, even more importantly, that these changes contribute for countries' growth rates divergence, the vast majority of growth models neglect the relevance of structural changes to promoting countries' growth. Most endogenous and neo-Schumpeterian growth models focus on the importance of activities, such as R&D and education, to understand the process of innovation and growth. However, with some notable exceptions, they are sector-indifferent[75], which implies that structural changes have no role in explaining long-term growth.

The aim of this chapter is to present a sectoral model to explain the importance of structural change and countries' growth in the long term, as well as to apply this model to identify those sectors able to guarantee the highest growth rates based on the results of the former chapters. This chapter shows that although Kaldor has stressed the importance of structural change for growth, Kaldorian (and Post-Keynesian) growth models do not fully incorporate this issue, and hence they are unable to present a convincing explanation for the origin of cumulative causation processes in open eco-

[75]Palma (2004) presents a distinction between sector-specific and activity-specific models. According to the author, in endogenous growth models increasing returns may be generated by research-intensive activities, but they are not explicitly associated with the size, depth or strength of one specific sector.

nomies.

Some Kaldorian models explain how a process of cumulative causation takes place considering a one-sector model, such as the model presented by Setterfield (2011). However, these models do not explain the origin of this cumulative causation process. Essentially, they explain countries' growth divergence based on past growth, but they do not explain why past growth rates have diverged. In these models, the importance of sectoral structure of production and trade is not explicit, and thus structural changes in favour of industrial activities, for example, do not have any impact on countries' growth rates.

On the production side, Kaldor (1966, 1967) argued that sectors have different degrees of increasing returns to scale and it is important to explain a cumulative causation process in which countries' growth rates accelerates due to internal forces. Although some single-sector models incorporate the notion of increasing returns to scale, such as Dixon and Thirlwall (1975) did in the context of an open economy, it takes many years for this notion be incorporated into multisectoral demand-led models, and thus applied to explain why cumulative causation depends on the sectoral structure of production, such as presented by Fiorillo (2001). Fiorillo's model shows that countries' growth rates depend on the sectoral specialisation, and sectoral specialisation depends, in turn, on aggregate growth. Based on this, he explains cumulative causation as a consequence of sectoral changes. His model, however, does not take into account that economic growth in open economies is balance-of-payments constrained, and thus it does not show how increasing returns impact on income elasticities (and vice versa) to explain cumulative causation in open economies.

On the demand side, Pasinetti (1981, 1993) stressed the importance of sectoral elasticities of demand to explain structural change and the relation to unbalanced economic growth. Although his Structural Economic Dynamics (SED) model brings an important issue into the debate on the importance of structural changes for economic growth, it was only a quarter of a century later that Araujo and Lima (2007) applied the SED approach to understand a growth process in open economies (based on Thirlwall's law). These authors, however, do not consider any impact of endogenous technological progress in their models, and thus cumulative causation does not take place either in Pasinetti's SED approach or in Araujo and Lima's multisectoral version of Thirlwall's law. Araujo (2013) presents an alternative approach for this process. In his model, technological progress is assumed as endogenous in a SED model, and the balance-of-payments constraints emerge from the multisectoral Thirlwall's law. The author, however, considers that dynamic increasing returns to scale affects only price competitiveness, and, once the main determinant of international competitiveness is non-price factors (as we will see Section 4.2), it has little role in explaining the divergence in countries' growth divergence[76].

These two aspects of structural change (the demand- and the supply-side), however, are rarely considered together in a multisectoral model. Divergence in countries' growth rates in Kaldorian models are explained by different degrees of increasing returns among sectors on the supply-side *or* by different income elasticities of exports and imports on the demand-side. Nevertheless, it is not explained by *both* factors together. In this vein, a model that combines different sectoral degrees of increasing returns and income elasticities of demand is fundamental to understanding the dynamics of growth rates divergence in open economies and the importance of structural changes to trigger a cumulative causation process.

Furthermore, one aspect of crucial relevance to economic growth models is its policy implications. The fact that neoclassical, endogenous, neo-Schumpeterian and Post-Keynesian growth models do not fully incorporate the existence of different sectors with different characteristics implies that policy interventions in favour of one sector have limited impact on countries' long-term growth. In order to understand it, this chapter analyses how a policy intervention promoting one sector to the detriment of the others might promote acceleration (or de-acceleration) of countries' growth rates in the long term through a process of cumulative causation.

Besides this introduction, this chapter is divided into five sections. Section 2 discusses cumulative causation in Kaldorian models and argues for the need for a sectoral approach. Section 3 presents a model that combines the issues above mentioned to explain cumulative causation in a multisectoral framework. Section 4 simulates the model for the four extreme theoretical cases considering two sectors. Section 5 simulates the model for a case based on parameters estimated in the previous chapters to evaluate what those sectors are that can trigger a cumulative causation process. Finally, in the last section, the concluding remarks are presented.

[76]In his model, cumulative causation emerges from the fact that countries have different sectoral elasticities of demand according to their income per capita. As countries grow, the demand shifts towards products with higher income elasticities, as well as production. Consequently, countries can grow at higher growth rates.

4.2 Cumulative causation in Kaldorian models

4.2.1 Cumulative causation and price competitiveness

Based on the Kaldorian approach, which stresses the existence of increasing returns to scale in manufacturing activities, as well as the importance of exports as an autonomous source of demand (Kaldor, 1966; 1970), Dixon and Thirlwall (1975) developed the first Export-Led Cumulative Causation (ELCC) model. The basis of this model is Verdoorn's law, which states that more rapid growth in production increases productivity growth. Dixon and Thirlwall's model assumed this law for regional competition and argued that this productivity growth reduces production prices. As countries become more internationally competitive due to increases in price competitiveness, exports and production are stimulated, and thus a circular and cumulative process takes place.

Setterfield and Cornwall (2002) present a more complex version of this model. In their model, productivity stimulates economic growth by a "productivity regime", as expressed by Dixon and Thirlwall (1975). Nevertheless, economic growth is also stimulated by demand growth, which characterises a "demand regime". In this formulation, productivity growth and demand growth constitute a system of two linear equations, and the resolution of this system yields a stable equilibrium demand[77].

One of the limitations of these models is that both are considered inappropriate to describe a stable long-run equilibrium in an open economy. According to Thirlwall and Dixon (1979), the growth rate provided by the ELCC model is inconsistent with balance-of-payments constraints (Thirlwall, 1979; McCombie and Thirlwall, 1994). As this model does not consider this constraint, it is insufficient to explain economic growth in the long term. Thus, Thirlwall and Dixon (1979) modified the original model to incorporate an import demand function, and hence a balance-of-payments constraint on economic growth.

Blecker (2010) did the same for the model developed by Setterfield and Cornwall (2002). In Blecker's version, two equilibriums are obtained for a growing economy: the balance-of-payments constrained growth (BPCG) solution and the ELCC solution. The author then attempts to reconcile these two growth rates. According to him, if a country is experiencing a virtuous cycle of export-led growth, the ELCC solution prevails, but only in the medium term. However, in the long term, countries' growth

[77] Blecker (2010) notes that disequilibrium in this model implies ever-rising or ever-falling growth rates, which is not plausible in the long term.

rates are given by the BPCG solution.

Both the Thirlwall and Dixon (1979) and Blecker (2010) models are based on the assumption that the natural rate of growth (given by productivity and labour force growth) does not affect the income elasticities for imports or exports[78]. Essentially, the mechanism responsible for the cumulative process is price competitiveness. A faster growth of output increases productivity growth, which, in turn, increases price competitiveness because it reduces domestic inflation relatively to world inflation. Consequently, exports are stimulated and, due to multiplier and accelerator effects, output grows faster, generating a cumulative process.

However, one of the assumptions of Thirlwall's law is that there are no relative price effects in the long run, and hence the mechanism from which cumulative causation is presented in Dixon-Thirlwall's model does not play any role in BPCG models. Thereby, due to the assumption that relative price changes have no effects in the long term, the natural rate of growth responds endogenously to BPCG, and thus increasing returns to scale do not affect growth rates in the long run. Countries' long-term growth rates are uniquely determined by Thirlwall's law, and the ELCC growth is only a weak attractor.

Nevertheless, it does not imply that cumulative causation does not happen in BPCG models, even in a one-sector model. The existence of cumulative causation in Thirlwall's law emerges from another perspective. Setterfield (2011) shows that instead of reducing prices, productivity growth (derived from Verdoorn's law) increases the quality of the products. Because consumers value quality, the existence of increasing returns to scale might positively affect countries' income elasticities of demand for imports and exports through *non-price competitiveness.*

4.2.2 Cumulative causation and non-price competitiveness

The most important determinant of long-run growth of exports and imports is non-price factors, such as goods quality, reliability and speed of delivery. McCombie and Roberts (2002:92) argue that countries' success in the world market is due to product innovation rather than to reducing the prices of existing products. According to McCombie and Thirlwall (1994:268), many studies show that non-price factors differ substantially between similar products, and that manufacturers face a downward

[78]Some studies, such as Vogel (2009), León-Ledesma and Lanzafame (2010), and Lanzafame (2011), have investigated the relationship between these two growth rates and the actual growth rate and found unidirectional causality from the BPCG rate to the natural growth rate.

sloping curve. The evidence suggests that price competition is not of great importance explaining exports (and imports).

Analysing some developed economies, Kaldor (1978) found that those countries that have experienced the greatest growth rates in prices also have had the greatest increase in their market share. This fact was known as “Kaldor Paradox”, because if price-elasticities were relevant to explain the market shares, the most suitable result should be the converse. Kaldor argued that the increase in prices is not the cause, but a consequence of improvements in the quality of goods. These strong trends in market shares, instead of capturing relative price changes, captured the effects of changes in non-price competitiveness.

In the same vein, Fagerberg (1988) discusses what *is* and what *should be* "international competitiveness" in the economic literature. Although the most popular approach focused on “growth in relative unit labour costs” and its determinants, several studies indicate that its effects on trade flows are rather weak. Alternatively, technological factors (scope for imitation and technological competitiveness) and other non-price factors, such as ability to deliver, are the main explanations for export and import growth in the long term.

Thereby, the focus of cumulative causation models have to change from price to non-price competition, once the latter is the main determinant of countries’ exports and imports. In order to show that cumulative causation exists even considering that there are no price effects in the long term, this chapter follows Setterfield’s (2011) approach for Thirlwall’s law with endogenous non-price elasticities. Setterfield starts by assuming that income elasticities are functions of domestic and foreign productivity levels[79], as follows:

$$\varepsilon = aQ \tag{4.1}$$

and

$$\pi = bQ^* \tag{4.2}$$

where Q and Q^* are the domestic and world productivity levels, respectively.

Defining the income elasticities ratio as $\kappa = \frac{\varepsilon}{\pi}$, and so, combining the expressions above, we have:

[79] According to Fagerberg (1988), economic growth may influence technological competition through demand-induced innovation, even though innovation activity seems to depend more on technological opportunities and the resources devoted to innovation than on demand conditions.

$$\dot{\kappa} = \kappa(q - q^*) \tag{4.3}$$

Assuming that domestic and international growth rates present increasing returns to scale following a typical Verdoorn form, equations (4.4) and (4.5) measure the impact of output growth on productivity growth, and they show that it is strictly related to the degree of increasing returns, as follows:

$$q = \lambda + by \tag{4.4}$$

and

$$q^* = \lambda^* + b^* z \tag{4.5}$$

where b is Verdoorn coefficient.

As $\lambda^* = \lambda$ and $b^* = b$, as assumed in Setterfield (1997), changes in the income elasticities ratio can be expressed as:

$$\dot{\kappa} = \kappa b(y - z) \tag{4.6}$$

Finally, because in the long term $y = \kappa z$ (Thirlwall, 1979), it follows that:

$$\dot{\kappa} = \kappa y(\kappa - 1)z \tag{4.7}$$

This result shows that for $\kappa = 1$, the income elasticities ratio is stable. However, for $\kappa > 1$ there will be an increase of income elasticities ratio, and for $\kappa < 1$ there will be a decrease. It means that growth rates tend to diverge in the long term, which characterises a cumulative causation process.

Although this simple model is able to show a possible mechanism behind the growth rate divergence across countries, it does not show the origins of this divergence, because it explains countries' growth rates based on past growth rates, but it does not explain why past growth rates diverge. In this model, a faster economic growth initiates a cumulative causation process independently of its sources, and it has no effects on production and trade structures. If a country is growing faster than the rest of the world due to an increase in demand for natural resources, for example, a process of ever-increasing growth rates will take place no matter if manufacturing is growing relatively slower than the rest of the world.

These results are obtained because this model ignores the consequences of structural change in economic growth. Once the structure of the economy remains unchanged (or these changes have no effects on economic growth), the origin of cumulative causation is not explicitly showed, and its positive and negative consequences are underestimated.

Nevertheless, as stressed by Pasinetti (1993), a simple observation of any series of empirical data suggests, without any shadow of doubt, that countries present structural change in their development process, and it has undoubted consequences on their growth rates. Thereby, even though to ignore structural changes is a good artifice to facilitate the understanding of growth processes through economic models, it suppresses the effects of one of the most important aspects of economic development.

4.3 A sectoral cumulative causation model in a Kaldorian line

By promoting structural changes in the sectoral composition of production and trade, a country can trigger a process of cumulative causation, and hence initiate a process of increasing growth rates. The dynamic interaction between sectoral income elasticities of demand and increasing returns to scale is capable of accelerating (or reducing) countries' growth rates and determining their growth pattern in the long term. The following model presents a possible channel through this process can occur. Essentially, it shows that promoting sectors with high income elasticities of demand is not enough to trigger a cumulative process. Once a cumulative causation process comes from the interaction between these sectoral specificities, countries have to promote those sectors with both characteristics to start a process of growth rate acceleration.

4.3.1 The dynamics of balance-of-payments constrained growth rate

The starting point of the model is that in the long term, growth is balance-of-payments constrained, and thus output growth depends on the weighted elasticities ratio, such as presented by Araujo and Lima (2007) in the multisectoral version of Thirlwall's law[80]:

$$y_B = \frac{\sum \omega_{Xi}\varepsilon_i}{\sum \omega_{Mi}\pi_i} z \tag{4.8}$$

[80] This version of Araujo and Lima (2007)'s model is presented by Setterfield (2011).

where ω_{Xi} is the share of sector i's exports in the total exports, ω_{Mi} is the share of sector i's imports in the total imports, and ε_i and π_i are the sectoral income elasticities of demand for exports and imports, respectively.

Based on the standard demand theory, which assumes multiplicative import and export functions[81], and by considering that relative prices do not present an ever-increasing or ever-decreasing growth rates, such as assumed by Thirlwall (1979), the growth rate of sectoral weight of exports and imports may be expressed as:

$$\frac{\dot{\omega_{Xi}}}{\omega_{Xi}} = x_i - x = (\varepsilon_i - \omega_\varepsilon)z \tag{4.9}$$

and

$$\frac{\dot{\omega_{Mi}}}{\omega_{Mi}} = m_i - m = (\pi_i - \omega_\pi)y \tag{4.10}$$

where $\omega_\varepsilon = \sum \omega_{Xi}\varepsilon_i$ and $\omega_\pi = \sum \omega_{Mi}\pi_i$ are the weighted elasticities of demand for imports and exports respectively.

Following Setterfield (2011) and McCombie and Thirlwall (1994), who assume that technical progress improves income elasticities of exports and imports because it increases product differentiation and hence non-price competitiveness[82], the sectoral elasticities of demand are assumed to be positively related to the productivity growth differential between the country under consideration and the rest of the world. Thereby, the growth rate of these elasticities may be written as a function of the difference between sectoral domestic and external productivity growth rates, as follows:

$$\frac{\dot{\varepsilon_i}}{\varepsilon_i} = \phi_i(q_i - q_i^*) \tag{4.11}$$

and

$$\frac{\dot{\pi_i}}{\pi_i} = \phi_i(q_i^* - q_i) \tag{4.12}$$

where ϕ_i is a parameter to measure the impact of productivity growth differential on income elasticities of demand for exports and imports.

As discussed in Chapter 3, once it is assumed that factor inputs respond to demand growth, productivity is endogenously determined by output growth (according to Verdoorn's law). Thereby, elasticities growth rates are determined by the difference

[81] These functions can have, for example, a multiplicative form: $X_{it} = \left(\frac{P_{it}^* E_t}{P_{it}}\right)^{\varphi_i} (Z_t)^{\varepsilon_i}$ and $X_{it} = \left(\frac{P_{it}}{P_{it}^* E_t}\right)^{\eta_i} (Z_t)^{\pi_i}$.

[82] To the detriment of a technological progress that reduces costs, such as assumed by Dixon and Thirlwall (1975) and Araujo (2013).

between domestic and external output growth rates[83], as well as by a factor, λ, which measures the impact of exogenous technological changes, as follows:

$$\frac{\dot{\varepsilon}_i}{\varepsilon_i} = \phi_i[(\lambda_i - \lambda_i^*) + b_i(y_i - z_i)] \tag{4.13}$$

and

$$\frac{\dot{\pi}_i}{\pi_i} = -\phi_i[(\lambda_i - \lambda_i^*) + b_i(y_i - z_i)] \tag{4.14}$$

By assuming that sectoral exogenous technological change is the same domestically and for the rest of the world ($\lambda_i = \lambda_i^*$), these equations show that the faster the growth of sector i domestically compared to the rest of the world is, the faster the sectoral income elasticity of exports will increase, and the faster income elasticity of imports will decrease. Moreover, these equations also show that the higher the Verdoorn coefficient of sector i is, the higher the impact of a sectoral faster growth rate on the elasticities is, and, consequently, the higher its impacts on export and import growth rates will be.

A faster growth of sectoral exports and a de-acceleration of sectoral imports, however, do not imply that countries' BPCG rates will necessarily increase. From equation (4.8), it is possible to see that if sector i presents high income elasticities of demand for exports and low income elasticities of demand for imports, an increase in its weights positively affects the long-term growth rate, y_B. However, if this sector presents low income elasticities of demand for exports or high income elasticities of demand for imports, the results may be the converse.

Thereby, with the aim of analysing the impact of a faster growth of sector i on countries' long-term growth rates, the growth dynamics of countries' BPCG rates are expressed as:

$$\frac{\dot{y_B}}{y_B} = \frac{\dot{\omega_\varepsilon}}{\omega_\varepsilon} - \frac{\dot{\omega_\pi}}{\omega_\pi} + \frac{\dot{z}}{z} = \sum \frac{\omega_{Xi}\varepsilon_i}{\omega_\varepsilon}\left(\frac{\dot{\omega_{Xi}}}{\omega_{Xi}} + \frac{\dot{\varepsilon}_i}{\varepsilon_i}\right) - \sum \frac{\omega_{Mi}\pi_i}{\omega_\pi}\left(\frac{\dot{\omega_{Mi}}}{\omega_{Mi}} + \frac{\dot{\pi}_i}{\pi_i}\right) + \frac{\dot{z}}{z} \tag{4.15}$$

Finally, replacing equations (4.9), (4.10), (4.13) and (4.14) in (4.15), and remembering from equation (4.8) that $y_B = \frac{\omega_\varepsilon}{\omega_\pi}z$, the equation that presents changes in countries' long-term growth rates (given by multisectoral Thirlwall's law) in terms of

[83] We assume that Verdoorn's coefficients are sector-specific, but they are the same for the country under consideration and the rest of the world.

its sectoral structure is given by:

$$\dot{y_B} = \sum \frac{\omega_{Xi}\varepsilon_i}{\omega_\varepsilon}[(\varepsilon_i - \omega_\varepsilon)z + \phi_i b_i(y_i - z_i)]z -$$

$$- \sum \frac{\omega_{Mi}\pi_i}{\omega_\pi}[(\pi_i - \omega_\pi)z + \phi_i b_i(y_i - z_i)]z + \frac{\omega_\varepsilon}{\omega_\pi}\dot{z} \quad (4.16)$$

This equation presents the dynamics of countries' BPCG rates from a sectoral perspective. The first term presents the dynamics of the weighted income elasticities of demand for exports, and the second, the dynamics of the weighted income elasticities of demand for imports. It is possible to see from this equation that sectoral growth rates differential to the rest of the world plays an important role in this dynamics, and its impact depends upon the sectoral Verdoorn coefficient, as well as upon the sectoral income elasticities of demand for exports and imports.

4.3.2 Impacts of structural changes on the BPCG rates

The impact of a faster growth rate of a given sector, y_i, on countries' long-term growth rate dynamics can be analysed from equation (4.16). A faster growth of a given sector can be interpreted as a structural change in countries' sectoral compositions of output if the other sectors growth rates are not affected. Hence, by considering that the world output growth is not affected by changes in the growth rate of the country under consideration, as well as the growth rates of others sectors are not affected by a faster growth rate of the given sector, this impact can be described as:

$$\frac{\partial((\dot{y_B})}{\partial(y_i)} = \frac{d(\dot{y_B})}{d(y_i)} + \frac{d(\dot{y_B})}{d(y)}\frac{d(y)}{d(y_i)} \quad (4.17)$$

This equation shows that a faster growth of sector i has two impacts on countries' long-term growth rates. Firstly, it has a direct impact (expressed by term in the first term), which shows the impact of a faster growth of the sector on the income elasticities of demand for imports and exports, as well as on the weight of each sector in exports and imports. Moreover, it has an indirect impact. A faster growth of a sector (considering that other sectors growth rates remains constant) increases total output growth rate, according to this sector weight in the economy.

Based on equation (4.16), the indirect impact can be described as

$$\frac{d(\dot{y_B})}{d(y)}\frac{d(y)}{d(y_i)} = \left(1 - \sum \frac{\omega_{Mi}\pi_i}{\omega_\pi}\frac{\pi_i}{\omega_\pi}\right)\omega_i z \tag{4.18}$$

where $omega_i$ is the weight of sector i's output in total output.

Because $1 - \sum \frac{\omega_{Mi}\pi_i}{\omega_\pi}\frac{\pi_i}{\omega_\pi}$ is approximately zero[84], a faster growth of total output does not accelerate the long-term countries' growth rates, and the impact of a faster growth of sector i can be reduced to its direct impact, as follows:

$$\frac{d(\dot{y_B})}{d(y_i)} = \phi_i b_i \left(\omega_{Xi}\varepsilon_i + \omega_{Mi}\pi_i \frac{\omega_\varepsilon}{\omega_\pi}\right)\frac{z}{\omega_\pi} \tag{4.19}$$

From this equation, it is possible to verify that the long-term growth rate of a country accelerates when the sectors under consideration grow faster. However, this acceleration in the BPCG rate depends on the sectoral Verdoorn coefficient and the sectoral income elasticities of demand for imports and exports. The higher the Verdoorn coefficient and the income elasticities of the sector under consideration is, the higher the impact on the BPCG rate is.

On the export side, a faster growth of the sector under consideration affects positively its income elasticity, because it increases the non-price competitiveness of this sector. Consequently, the weighted income elasticity of demand for exports will increase, positively affecting the country's long-term growth rate. On the import side, a faster growth of the sector under consideration has a negative impact on its income elasticity of demand for imports. Here, an increase on non-price competitiveness reduces its elasticity because the country will demand less of this product, once the country is be able to produce it domestically. Consequently, the weighted income elasticity of demand for imports will decrease, reducing the BPCG rate.

Until now, it has been considered that a faster growth of a given sector does not affect the growth rate of others sectors. However, if one considers, alternatively, that a faster growth of one sector is compensated for by a reduction in another sector's growth rate (that will be considered here as sector j) to keep the actual growth rate of the country, y, constant, equation (4.17) has to be modified. The impact of sector i's faster growth can be split into the direct impact, such as before, and the impact through sector j's growth rate:

[84] If income elasticity of demand for imports is the same among sectors, $\frac{\pi_i}{\omega_\pi} = 1$ and thus the impact of structural changes on the dynamics of countries' BPCG is null. Thus, the difference between the income elasticities must be very high to the indirect impact have some significant effect on the dynamics of countries' BPCG rates.

$$\frac{\partial(\dot{y_B})}{\partial(y_i)} = \frac{d(\dot{y_B})}{d(y_i)} + \frac{d(\dot{y_B})}{d(y_j)}\frac{d(y_j)}{d(y_i)} \tag{4.20}$$

Taking into account the impact on others sectors' growth rates is important because it shows that, in contrast to one-sector models, a multi-sectoral approach can explain how a process of cumulative causation may take place even if the actual growth rate of a country remains constant.

Considering that $y = \omega y_i + \omega_j y_j$, where ω_i and ω_j are the weights of sector i and j in output, the impact of a faster growth of sector i on the dynamics of countries' BPCG rates is given by

$$\frac{\partial(\dot{y_B})}{\partial(y_i)} = \phi_i b_i \left(\omega_{Xi}\varepsilon_i + \omega_{Mi}\pi_i\frac{\omega_\varepsilon}{\omega_\pi}\right)\frac{z}{\omega_\pi} - \frac{\omega_i}{\omega_j}\phi_j b_j \left(\omega_{Xj}\varepsilon_j + \omega_{Mj}\pi_j\frac{\omega_\varepsilon}{\omega_\pi}\right)\frac{z}{\omega_\pi} \tag{4.21}$$

Equation (4.21) presents the two impacts of a faster growth of one sector to the detriment of the other: one positive, due to a faster growth of sector i, and one negative, due to a decrease in sector j output growth rate. The net impact depends on the relative Verdoorn coefficient and the relative elasticities. In the case of having $b_i > b_j$ and $\varepsilon_i,\pi_i > \varepsilon_j,\pi_j$, the impact of a faster growth of sector i will be an acceleration in the country's growth rate. On the other hand, if $b_i < b_j$ and $\varepsilon_i,\pi_i < \varepsilon_j,\pi_j$, the impact of a faster growth of sector i will be negative, reducing the BPCG rate.

At this point, we reach the main contribution of a multi-sectoral model. In single-sector models, a faster output growth is necessary to start a cumulative process. In a multi-sectoral model, it is not necessary. A cumulative causation process can be triggered by structural changes even if the growth rate of output is, at first, not affected. Because sectors have different income elasticities of demand for exports and imports, and they present different Verdoorn coefficients, specialisation in some sectors can boost the balance-of-payments constrained growth rates and, once it implies a faster growth of output, a process of cumulative causation takes place.

Equation (4.21), however, does not show explicitly a cumulative causation process, because it does not establish any link between the BPCG rate and the actual growth rate. Only if the actual rate of growth is determined by the BPCG rate will this intervention trigger a process of cumulative causation in which countries' growth rates can diverge in the long term.

4.3.3 Interrelatedness, lock-in and the limits for cumulative causation

As discussed in the latter subsection, promoting a structural change towards sectors with a Verdoorn coefficient and income elasticities higher than the average is essential to trigger a cumulative causation process and, thus, to accelerate countries' long-term growth rates. However, there are some limits for this process, and equations (3.19) and (3.21) have not taken into account these limits.

According to Setterfield (1997), the Verdoorn coefficient captures the impact of a faster output growth on productivity via increasing returns to scale. However, because these increasing returns can be captured not only from intangible channels, but also from accumulation of tangible fixed capital and specific organisation forms, the ability of a region to realise increasing returns may be impaired if it suffers from interrelatedness. The author argues that interrelatedness – the interconnection between components of production process – can lead to a region becoming "locked-in" to a certain technique of production inherited from the past. Moreover, based on Frankel's (1955) view, Setterfield argues that interrelatedness (and, thus, the probability of a region becoming "locked-in") is higher the faster the growth is within the context of a certain technique of production. According to him, a faster growth is a context of a certain technique causing a faster proliferation of interrelatedness, and more likely it becomes that a region will experience lock-in in to this technique. Thereby, previous fast growth rates of output may have a negative effect on productivity and countries' competitiveness, rather than (only) a positive effect, as predicted by Verdoorn's law.

McCombie and Roberts (2002) agree with Setterfield and go further. According to them, fast growth rates in previous period might make continuous adaptation difficult because they tend to encourage the lock-in of a production process. On the other hand, low previous growth rates must have a positive impact as a poor performance give rise to a sense of dissatisfaction and thus to pressure for reform of economy's production structure.

Thereby, formally speaking, specifying competitiveness as a negative function of previous growth rates is not a sufficient condition for having a historical growth model. According to McCombie and Roberts, it is necessary to consider that competitiveness is a function of past growth rates, but as a "strong non-linear function". They argue that while high values of previous growth rates may be allowed to have a negative impact, low values have a positive impact on competitiveness.

In the context of the model discussed here, where competitiveness is predominantly non-price competitiveness and it is represented by the sectoral income elasticities of demand for imports and exports, following McCombie and Roberts (2002), equations (4.11) and (4.12) can be re-written as[85]:

$$\frac{\dot{\varepsilon}_i}{\varepsilon_i} = \phi_i[b_i(y_i - z_i) - \varphi_i(y_i - z_i)^2] \tag{4.22}$$

and

$$\frac{\dot{\pi}_i}{\pi_i} = -\phi_i[b_i(y_i - z_i) + \varphi_i(y_i - z_i)^2] \tag{4.23}$$

where φ measures the impact of interrelatedness.

Therefore, a faster growth of a given sector increases the income elasticity of demand for exports and decreases the income elasticity of demand for imports due to Verdoorn's law, such as discussed before, but, at sufficiently high growth rates, the impact is reversed and non-price competitiveness start decreasing.

Based on these equations for the income elasticities, equation (4.14) is re-specified as

$$\dot{y_B} = \sum \frac{\omega_{Xi}\varepsilon_i}{\omega_p i}[(\varepsilon_i - \omega_\varepsilon)z + \phi_i b_i(y_i - z_i) - \phi_i\varphi_i(y_i - z_i)^2]z -$$

$$-\sum \frac{\omega_{Mi}\pi_i\omega_\varepsilon}{(\omega_\pi)^2}[(\pi_i - \omega_\pi)y - \phi_i b_i(y_i - z_i) + \phi_i\varphi_i(y_i - z_i)^2]z + \dot{z} \tag{4.24}$$

Hence, the impact of a faster growth of sector i (considering that it is not compensated by a lower growth of other sectors), can be rewritten as:

$$\frac{\partial(\dot{y_B})}{\partial(y_i)} = \phi_i[b_i - 2\varphi_i(y_i - z_i)]\left(\omega_{Xi}\varepsilon_i + \omega_{Mi}\pi_i\frac{\omega_\varepsilon}{\omega_\pi}\right)\frac{z}{\omega_\pi} \tag{4.25}$$

Equation (4.25) explicitly shows the main structure of a historical model with cumulative causation but with the possibility of reversion, such as discussed by Setterfield (1997) and McCombie and Roberts (2002). Because income elasticities are endogenous

[85] Considering that exogenous technological change is the same domestically and for the rest of the world.

to previous growth rates, a faster growth of the sector under consideration increases the long-term growth rates due to the existence of increasing returns to scale. However, because it is not linear, at sufficiently high growth rates the effect is reversal and country's long-term growth rates start decreasing as it can lead to a region becoming "locked-in" to a certain technique of production.

Thereby, a faster growth of the sector under consideration can stimulate through non-price competitiveness a cumulative process of increasing growth rates. However, due to the increasing possibility of a country become locked-in, the long-term growth rate starts decreasing at $b_i - 2\varphi_i(y_i - z_i) = 0$. It means that if the difference between domestic and world output growth in sector i is larger than $\frac{b_i}{2\varphi_i}$, the long-term growth rate of the country under consideration will decrease.

4.3.4 Technological gap and the opportunities to catch up

Equation (4.11) and (4.12) assumes Verdoorn's law to explain how productivity growth is positively affected by a faster growth of output and, hence, how the differential between domestic and external output growth can explain the dynamics of income elasticities. However, it was assumed that exogenous technological change is the same in the country under consideration and in the rest of the world, and so the fact that exogenous technological change may be different among countries has been ignored. On the one hand, exogenous technological change is determined by the scientific discoveries, which is strictly exogenous in the model. On the other hand, it might also depends on countries' distance to those in the innovation frontier. In this sense, it is also important to consider that the technological gap may affect productivity growth, and thus Verdoorn's law specification should control for that.

The relation between technological gap and the "growth bonus", as Cornwall and Cornwall (2002) named it, was discussed in the first chapter. Essentially, the authors who discuss this issue stressed that countries on a lower technological level than countries on the innovation frontier have the possibility of imitation and thus growing faster. Thereby, backwardness can be an advantage for productivity growth.

Assuming that λ_i has a strictly exogenous component, which is given by the exogenous technological change of the rest of the world ($\bar{\lambda}_i = \lambda_i^*$), but it also has a component that is determined by the technological gap, G_i, equations (4.11) and (4.12) can be rewritten, as follows to take into account the impact of technological gap on productivity growth:

$$\frac{\dot{\varepsilon_i}}{\varepsilon_i} = \phi_i[(\bar{\lambda_i} - \lambda_i^*) + f(G_i) + b_i(y_i - z_i)] \tag{4.26}$$

and

$$\frac{\dot{\pi_i}}{\pi_i} = -\phi_i[(\bar{\lambda_i} - \lambda_i^*) + f(G_i) + b_i(y_i - z_i)] \tag{4.27}$$

If f is a strictly positive function, thus, the impact of sectoral gap on productivity growth is always positive, as foolows:

$$\frac{df(G_i)}{d(G_i)} > 0 \Rightarrow \frac{d(G_i)}{d(q_i)} > 0 \tag{4.28}$$

Based on equations (4.26) and (4.27), equation (4.14) may be re-specified as:

$$\dot{y_B} = \sum \frac{\omega_{Xi}\varepsilon_i}{\omega_\pi}[(\varepsilon_i - \omega_\varepsilon)z + \phi_i b_i(y_i - z_i) + \phi_i f(G_i)]z -$$

$$-\sum \frac{\omega_{Mi}\pi_i\omega_\varepsilon}{(\omega_\pi)^2}[(\pi_i - \omega_\pi)y - \phi_i b_i(y_i - z_i) - \phi_i f(G_i)]z + \dot{z} \tag{4.29}$$

The impact of a faster growth of sector i will be the same presented in equations (4.19) and (4.21). However, such as discussed in the end of Section 4.3.2, these equations do not explicitly show a cumulative causation process, because there is no link between actual and BPCG rates. In the context that actual growth rates are determined by BPCG rates, a faster growth of a sector will have a positive impact on its elasticity of exports and a negative impact on its elasticities of imports. If the sector under consideration presents higher income elasticities than the average, a process of cumulative causation will take place because the BPCG will increase, and it, in turn, will positively affect the actual growth rate (of all sectors).

Nevertheless, this process of cumulative causation has two constraints. Firstly, if growth rates are sufficiently high, it will imply a reduction of elasticities due to the possibility of a country being "locked-in" to a specific technique of production (such as presented in Section 4.3.3). Secondly, because the sector under consideration is growing faster than the rest of the world, productivity of this sector will grow faster, and the technological gap will reduce. Consequently, if the level of productivity is sufficiently high, elasticities will stop increasing. Thus, although a process of cumulative causation happens and countries' growth rates become higher than before, instead of presenting ever-increasing growth rates, countries' growth rates will be constant in the long term.

This process of cumulative causation, however, is extremely complex in a multi-sectoral model because it involves variables in level, such as weight of sectors and technological gap, and variables in growth rates. Thereby, it will be presented through simulations in the next sections.

4.4 General simulations: possible results for a two-sector model

With the aim of assessing the impact of structural changes on countries' long term-growth rates, the model developed in the last section is simulated assuming different parameters for the sectoral income elasticities and the Verdoorn coefficient. From the results of these simulations, it will be possible to analyse what the necessary conditions are for these structural changes to affect positively countries' BPCG rates through a cumulative causation process.

The basic assumption of the model developed in the last section is that the multi-sectoral version of Thirlwall's law is the determinant of both long-term and short-term (or actual) growth rates. In the simulation, the latter, however, it is assumed to be determined with a lag, because the mechanisms that makes actual rate of growth to adjust towards the BPCG do not take place instantly.

Thereby, re-writing this model in discrete time, and considering this impact with a lag we have that:

$$y_t = y_{B,t-1} = \frac{\sum \omega_{Xi,t-1}\varepsilon_{i,t-1}}{\sum \omega_{Mi,t-1}\pi_{i,t-1}} z_{t-1} \tag{4.30}$$

where lower cases stand for growth rates (in discrete time).

If one assumes the sectoral weight of export and import growth rates based on (4.9) and (4.10), it might generate a problem of consistence because these equations are only linear approximations, and hence the summation of each sector's weight may be higher (or lower) than one. Thus, let us start by considering the growth rate of each sector's exports and imports separately:

$$x_{i,t} = \varepsilon_{i,t} z_t = (\varepsilon_{i,t-1} + \Delta\varepsilon_i) z_t \tag{4.31}$$

and

$$m_{i,t} = \pi_{i,t} y_t = (\pi_{i,t-1} + \Delta\pi_i) y_t \tag{4.32}$$

Following the idea behind equations (4.11) and (4.12), which assumes that sectorial income elasticities of exports and imports are determined by the level of productivity (because it reflects the quality of goods), and that productivity is determined by Verdoorn's law, the probability of lock-in and the technological gap (all in the previous period[86]), the income elasticities may be written as a function of the differential between domestic output growth and the rest of the world:

$$\Delta\varepsilon_i = \varepsilon_{i,t-1}\phi_i[b_i(y_{i,t-1} - z_{i,t-1}) - \varphi_i(y_{i,t-1} - z_{i,t-1})^2 + f(G_{i,t-1})] \tag{4.33}$$

and

$$\Delta\pi_i = -\pi_{i,t-1}\phi_i[b_i(y_{i,t-1} - z_{i,t-1}) - \varphi_i(y_{i,t-1} - z_{i,t-1})^2 + f(G_{i,t-1})] \tag{4.34}$$

Replacing equations (4.33) and (4.34) in (4.31) and (4.32), respectively, the growth rate of exports and imports can be expressed as a function of the following variables: the past elasticities, the differential between domestic and external sectoral output growth rates (in the previous period), the level of technological gap, the world growth rate and the actual growth rate:

$$x_{i,t} = \varepsilon_{i,t-1}\phi_i[1 + b_i(y_{i,t-1} - z_{i,t-1}) - \varphi_i(y_{i,t-1} - z_{i,t-1})^2 + f(G_{i,t-1})]z_t \tag{4.35}$$

and

$$m_{i,t} = \pi_{i,t-1}\phi_i[1 - b_i(y_{i,t-1} - z_{i,t-1}) + \varphi_i(y_{i,t-1} - z_{i,t-1})^2 - f(G_{i,t-1})]y_t \tag{4.36}$$

From these equations, it is possible to determine the level of exports and imports[87], which is necessary to obtain the weight of each sector in total exports and imports and thus the weighted income elasticity ratio.

Sectoral growth rates will be determined by two different process in different periods: (1) there will be periods that the economy will be growing without intervention, and thus sectoral growth rates will be determined by their income elasticities of demand; and (2) there will be periods where one sector is under direct intervention (and

[86] According to Setterfield (1997), competitiveness gains are associated with the realisation of induced technical progress (Verdoorn's law), and they require the accumulation of new capital, which will only come into productive use in some future period. Thereby, we assume that changes in elasticities are associated with growth rates in the previous period.

[87] They will be given, respectively, by $X_{i,t} = X_{i,t-1}(1 + x_{i,t})$ and $M_{i,t} = M_{i,t-1}(1 + m_{i,t})$.

thus its growth rate will be exogenously given) and the other sectors will grow at a rate that keeps the overall growth rate compatible with income growth rate[88]. In both cases, the overall economy will be growing at the same rate: the income growth rate. The difference is that whilst without intervention the distribution of sectoral growth rates is given by their relative income elasticities of demand, during the periods of intervention, one sector grows at a given growth rate and the others sectors compensate for this growth rate to keep overall growth rate compatible with income growth.

In mathematical terms, the growth rate of sector i is exogenously given during the periods of intervention, and during the period of non-intervention its growth rate given by its demand[89], as follows:

$$y_{i,t} = \frac{\pi^*_{i,t}}{\sum \omega_{i,t}\pi_{i,t}} y_t \tag{4.37}$$

Other sectors' growth rates are calculated assuming that the structure of production of the country under consideration is the same as the structure of rest of the world exports and imports, which implies that overall growth rates are the same independently of whether sector i is under intervention or not:

$$y_{j,t} = \frac{y_t - y_{i,t}\omega_{i,t}}{\omega_{j,t}} = \frac{y_t - y_{i,t}\omega^*_{Xi,t}}{\omega^*_{Xj,t}} \tag{4.38}$$

Finally, defining the variable that measures the technological gap based on the sectoral income elasticities ratio, $G_i = \frac{\varepsilon^*_i/\pi^*_i}{\varepsilon_i/\pi_i}$ (which means that there will be no gap, $G_i = 1$, if the sectoral income elasticities ratio is the same domestically and in the rest of the world[90], and that the gap will be as higher as the income elasticity ratio decreases), and assuming[91]:

[88] By intervention, it is assumed that a superior institution is able to determine the growth rate of a given sector. This procedure is applied only for explanatory reasons. The aim of this procedure is to show the impact of a faster growth of a given sector to the detriment to the others to evaluate its impact on countries' growth rates.

[89] The assumption that sectoral output growth reflects weights and elasticities of the rest of the world is only to make the model simple. Once we consider that countries grow at the same rate in the beginning and their growth rates are given by the same structure, this assumption only reflects the fact that changes in countries' elasticities of imports and exports due to increasing returns to scale do not play any role in domestic elasticities. An alternative assumption for sectoral growth rates could be the one presented by Trigg and Araujo (2014), which considers output multipliers. However, it will make the model even more complex, and it goes beyond the aim of this work.

[90] Because income elasticities is a measure for non-price competitiveness, and it reflects the quality of the goods produced, such as discussed in Section 4.2, this definition for technological gap is more suitable than the usual definition based on productivity differential.

[91] It means that the impact of the gap on productivity is null if there is no gap, but this impact

$$f(G_i) = \sigma_i(e - e^{(1/G_i)}) = \sigma_i(e - e^{(\varepsilon_i/\pi_i)}) \tag{4.39}$$

where σ_i is the impact of technological gap on productivity growth rate and $\varepsilon_i^* = \pi_i^*$, equations (4.30) and (4.35)-(4.39) are sufficient to start the simulation, as all variables can be determined by lagged variables[92].

However, in order to keep the model consistent in the long term, it is assumed that sectoral output growth in the rest of the world is equal to its demand, which implies that

$$z_{i,t} = \frac{\pi_{i,t}^*}{\sum \omega_{i,t}^* \pi_{i,t}^*} z_t \tag{4.40}$$

and that equations (4.36)-(4.39) also apply for the rest of the world.

Furthermore, it is assumed that at the starting period ($t = 0$), domestic growth rate is equal to the rest of the world's growth rate, once, at first, the weight of each sector in exports and imports are the same domestically and for the rest of the world, as well as each sector's export and import elasticities.

4.4.1 Specialisation in sectors with high elasticities and high Verdoorn coefficient

With the aim of analysing the impact of an intervention in favour of one sector to the detriment of the other on countries' long-term growth rates, the simulation assumes two different cases: with and without intervention. In both cases the economy starts with the same structure and the same elasticities of the rest of the world.

In the case of no intervention, during all series sectoral growth rates are given by the BPCG rate multiplied by the sectoral relative income elasticities of demand, such as presented by equation (4.37). As discussed before, it is important to guarantee that sectoral supply and demand growth rates are the same. In the case of intervention, three different periods are considered. During the first five periods there is no intervention, and hence both sectors are growing at the same growth rate of the rest of the world, which is given by the BPCG rate multiplied by the sectoral relative income elasticity of demand. During five periods of intervention (from periods 6 to

grows exponentially as the gap grows. Moreover, it is assumed that world gap is null because the gap is being measured in terms of world technology.

[92]With the exception of sectoral world output growth, which is considered as exogenously given.

10), sector i is growing at an exogenously given growth rate that is higher than the period without intervention, whilst the other sector, sector j, is growing at a lower growth rate to compensate for sector i's faster growth rate in order to keep the overall growth rate equal to the BPCG rate. Finally, after the intervention (from period 11 onwards), both sectors return growing at the BPCG rate multiplied by the sectoral relative income elasticities of demand. However, because during the period of intervention sectoral growth rates were different in the country under consideration and in the rest of the world (even though the overall growth rate was unchanged), the BPCG rate may have changed and the economy may grow faster or slower than if there were no intervention.

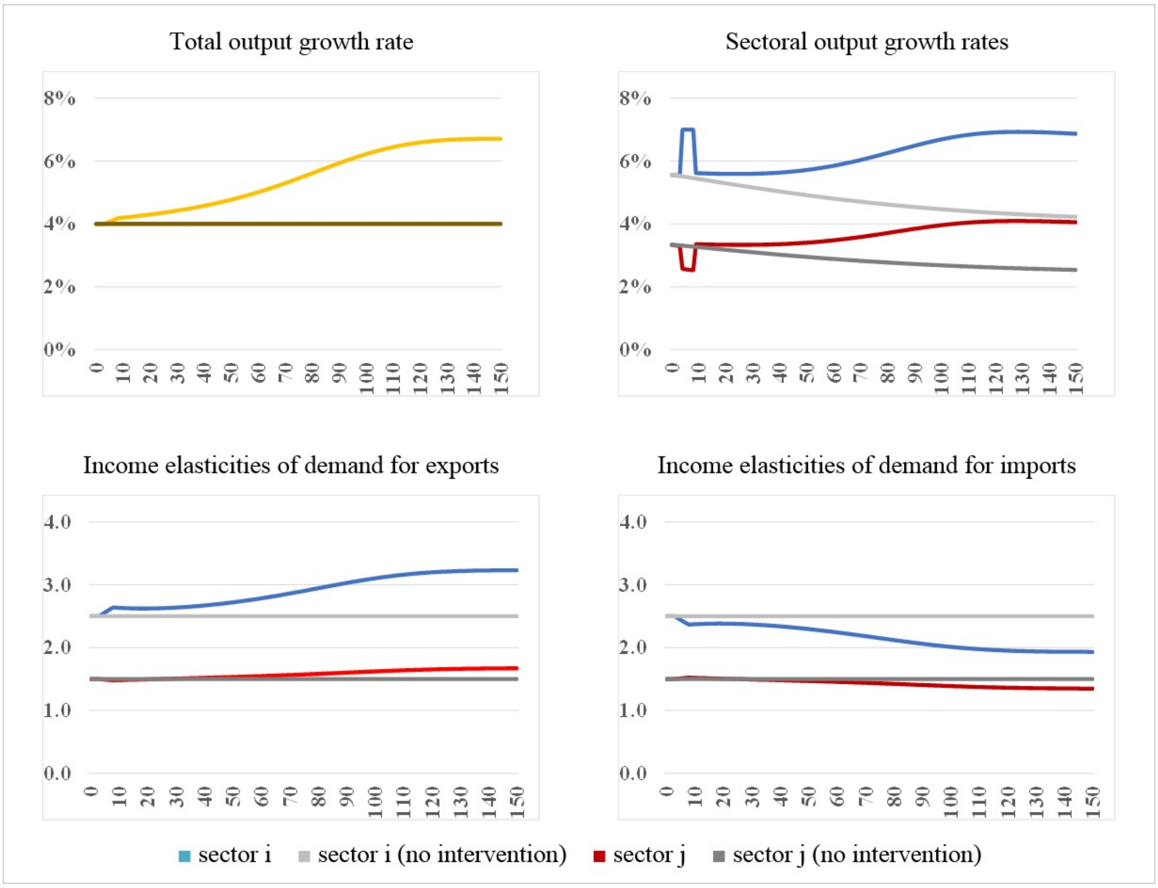
Simulations 1 and 2 assume an economy composed of two sectors that produce tradable goods. One of these sectors has the highest Verdoorn coefficient (and thus the highest degree of increasing returns) and the highest income elasticities of demand for imports and exports; the other, consequently, has the lowest Verdoorn coefficient and the lowest elasticities. Even though these are theoretical simulations, the sector with the high elasticities and Verdoorn coefficient may be interpreted as high-tech manufacturing in middle- and high-income countries based on the results of income elasticities of demand found in Chapter 2 and Verdoorn coefficients found in Chapter 3, whilst the other sector may be interpreted as low-tech manufacturing[93].

Figure 4.1 presents the results of Simulation 1, which is an intervention in the sector with high elasticities and a high Verdoorn coefficient. From this simulation, it is possible to understand the mechanisms through structural changes which may trigger a cumulative process of increasing growth rates. The upper left graph shows that a five-period intervention on relative sectoral growth rates can start a cumulative growth process, even if, at first, this intervention does not affect the total output growth rate.

As the sectoral output growth rates graph (upper right) shows, a five-period positive impact on sector i growth rate affects positively the long-term growth rate of this sector because it initiates a cumulative process. However, it does not affect negatively the other sector. Conversely, sector j is positively affected in the long term in spite of being negatively affected during the period of intervention.

[93]For middle- and high-income countries, the Verdoorn coefficient is higher in high-tech than in low-tech sector (Chapter 3). Income elasticities of demand for imports and exports are higher in high-tech sectors in all estimations (Chapter 2).

Figure 4.1: Simulation 1: impact of an intervention in the sector with the highest income elasticities and the highest Verdoorn coefficient



This process happens because, during the period of intervention, the faster growth rates of sector i affect positively its own income elasticity of demand for exports and negatively its own income elasticities of demand for imports due to the existence of increasing returns to scale. The converse impact on sector j's income elasticities, however, is less relevant because once this sector presents a lower degree of increasing returns, the impact on its own elasticities is relatively lower. Consequently, the economy as a whole grow faster due to an overall increase on the weighted income elasticities. Because the economy is growing relatively faster than the rest of the world, the income elasticities of demand for exports in both sectors increase permanently and the income elasticities of demand for imports decrease, triggering a process of cumulative causation.

Essentially, sector i's elasticity ratio is positively affected by the growth of the sector itself and by the growth of the economy as a whole, whilst sector j's elasticity ratio is negatively affected by the growth of the sector itself, but, on the other hand, it is positively affected by the growth of the economy. Thereby, an intervention that promotes a structural change in favour of the sector with the highest Verdoorn coefficient and the highest income elasticities of demand initiates a cumulative process of faster growth rates. In the analysed case, the growth rate of the economy increases from 4% to 7%, showing that structural changes in favour of an specific sector may promote significant acceleration in countries' growth rates[94].

This intervention, however, will not imply ever-increasing growth rates. Firstly, because the probability of a country becoming "locked-in" to a specific technology increases as growth rates increase, the greater the difference between countries' growth rates is, the harder it is for a country that is growing faster to keep accelerating. Secondly, because the positive impact of the technological gap on productivity will decrease as productivity grows, the income elasticities of demand for imports will stop decreasing and the income elasticities of demand for exports will stop increasing.

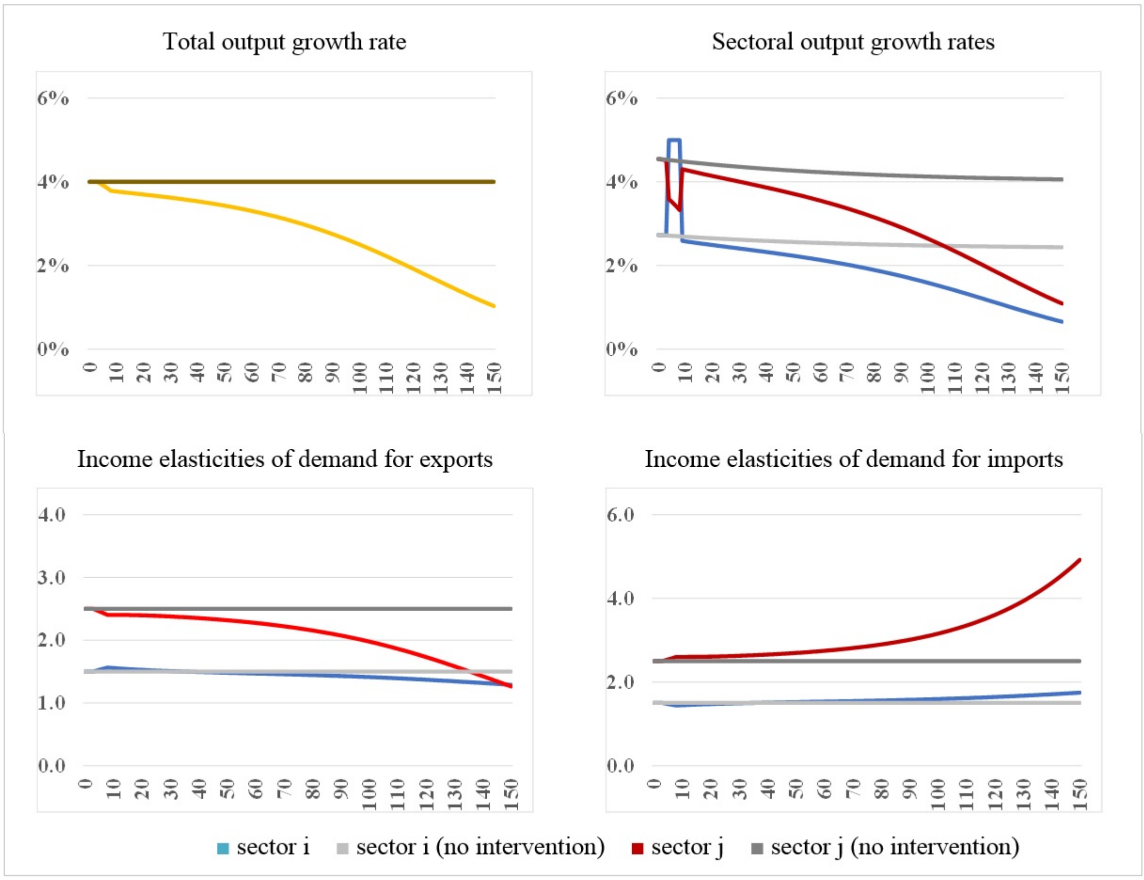
4.4.2 Specialisation in sectors with low elasticities and low Verdoorn coefficient

Simulation 2 analyses the impact of promoting the sector with the lowest Verdoorn coefficient and the lowest income elasticities, which may be interpreted as an intervention in favour of low-tech manufacturing in middle- and high-income countries. Figure 4.2 presents the results. As can be seen from the graph in the upper left side, an intervention that stimulates a faster growth of this sector (to the detriment of the other sector) negatively affects the economic growth rate, and it initiates a process of cumulative causation in which the country's growth rate decreases continuously.

The reason for this is the same presented before, but conversely. A faster growth of the sector with the lowest income elasticities positively affects its own income elasticity of exports and negatively affects its own income elasticities of imports, promoting a faster growth of this sector itself. However, because the sector with the highest Verdoorn coefficient is growing at lower rates in relation to the rest of the world, its elasticity of exports is decreasing and its elasticity of imports is increasing. The net impact on the weighted income elasticity ratio is negative, and hence output will grow at lower rates. Consequently, the income elasticities of demand for exports in both

[94]If one assume that each period refers to a quarterly or a year, it takes a long time to growth rates increase significantly (as can be seen from Figure 4.1, it takes 150 periods to total output growth rate increases by 3 p.p.). Thereby, this analysis must be seen in the very long run, and it has to be used to explain countries' secular stagnation or long-term growth acceleration

Figure 4.2: Simulation 2: impact of an intervention in the sector with the lowest income elasticities and the lowest Verdoorn coefficient



sectors will increase, and the elasticities of imports will decrease, negatively affecting the weighted income elasticities, which, in turn, will trigger a cumulative causation process of decreasing growth rates.

4.4.3 Specialisation in sectors with low elasticities and high Verdoorn coefficient

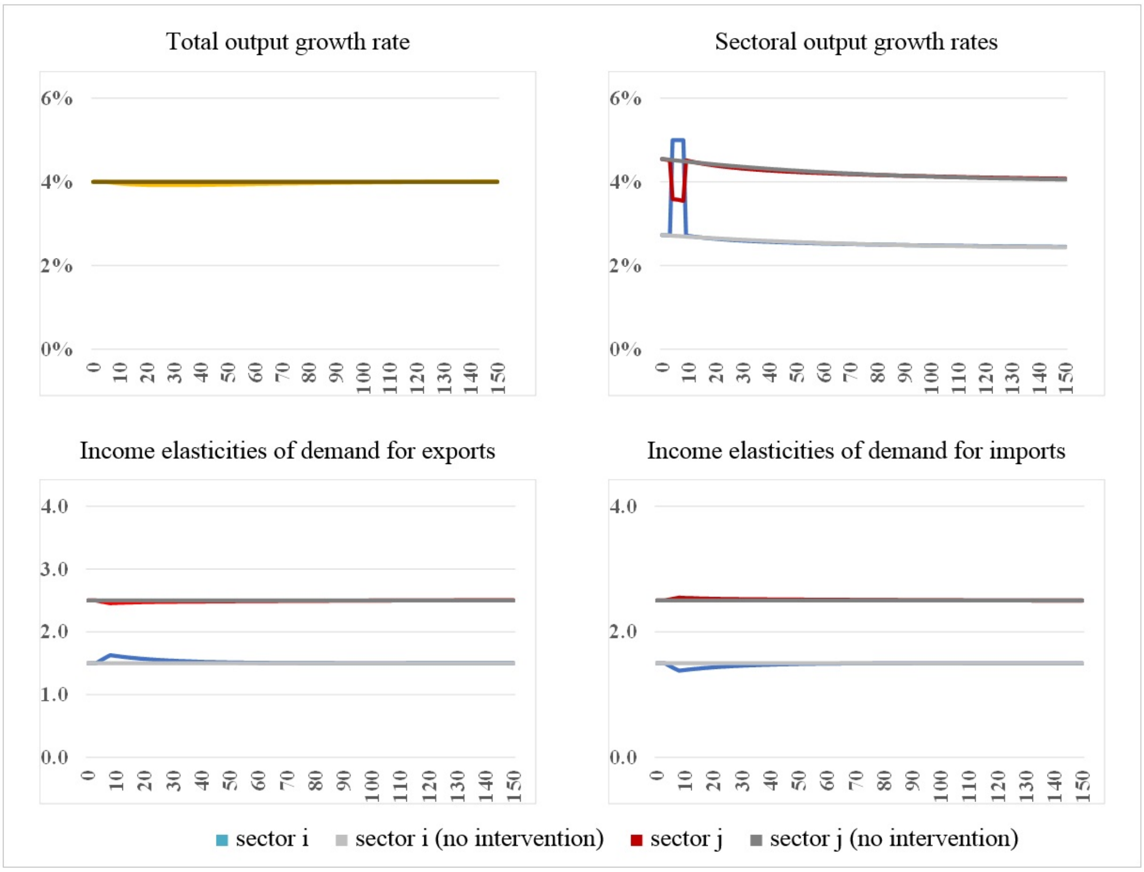
Simulations 3 and 4 also consider two sectors that produce tradable goods, but, in contrast to those presented before, one of these sectors presents the highest Verdoorn coefficient and the lowest income elasticities, and the other, the lowest Verdoorn coefficient and the highest income elasticities.

This analysis can be interpreted based on the findings of the latter chapters. The results of Chapter 3 showed that, for low-income countries, low-tech industries have higher degrees of increasing returns than high-tech industries, whilst the results of

Chapter 2 showed that income elasticities are higher in high-tech industries in all estimations.

Figure 4.3 presents the results for Simulation 3, which considers a five-period intervention in favour of the sector with the lowest income elasticities but the highest Verdoorn coefficient, such as low-tech industries in low-income countries. In contrast to the simulations presented before, the results presented here are not conclusive, because it depends on the elasticities and the Verdoorn coefficient.

Figure 4.3: Simulation 3: impact of an intervention in the sector with the lowest income elasticities but the highest Verdoorn coefficient



An intervention promoting a structural change in favour of the sector with the lowest income elasticities positively affects the income elasticity ratio of this sector, but it affects negatively the income elasticity ratio of the other sector. As in the former simulations, one sector is positively affected and the other is negatively.

Nevertheless, in contrast to those simulations, because the sector with the lowest income elasticity presents the highest Verdoorn coefficient, the positive effect on this sector's elasticity ratio is greater than the negative impact on the elasticity ratio of the other sector. Consequently, although the weight of those sectors with the lowest income elasticities will increase in total exports and decrease in total imports, the elasticity ratio of this sector will increase and, depending on the parameters, the latter effect may compensate for the former, and the weighted elasticities ratio will not be affected.

4.4.4 Specialisation in sectors with high elasticities and low Verdoorn coefficient

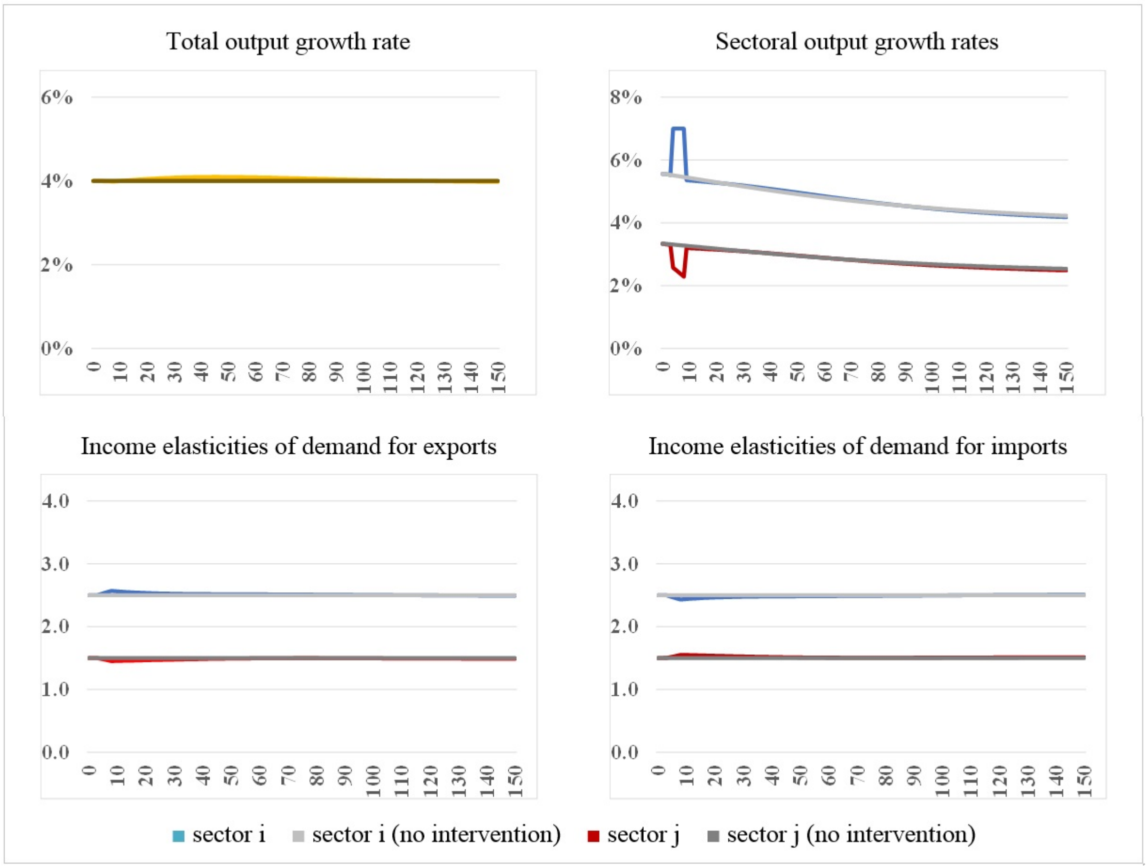
Finally, Simulation 4, presented in Figure 4.4, shows the impact of an intervention in favour of the sector with the highest income elasticities but the lowest Verdoorn coefficient. Based on the findings of the latter chapters, this sector may represent high-tech industries for low-income countries. Similar to the result obtained in the last simulation, the impact of a structural change in favour of this sector on total output growth rate is dubious: it depends on the parameters.

Although a faster growth rate of the sector with the highest elasticities increases its own income elasticity of exports and its share on total exports, as well as it decreases its own elasticity of imports and its share on total imports, these impacts may be offset by the impacts of the other sector. Because the sector negatively affected by the intervention presents the highest degree of increasing returns, its elasticities responds relatively faster to its growth rates and, thus, the weighted elasticities may respond negatively to this intervention.

Such as in the former simulation, the net impact depends on the relative size of the parameters. If the difference in the Verdoorn coefficient is great enough to compensate for the difference in elasticities, the weighted elasticities will decrease and hence the total output growth rate will drop. Nevertheless, if the difference in elasticities is greater enough to compensate for the difference in the Verdoorn coefficient, total output growth rate will increase, triggering a cumulative process of increasing growth rates.

The results obtained in these four theoretical simulations demonstrate that both sectoral income elasticities of demand and sectoral Verdoorn coefficients are important to explain the origin of a cumulative causation process. An intervention in favour of sectors with higher Verdoorn coefficients and income elasticities than the average,

Figure 4.4: Simulation 4: impact of an intervention in the sector with the highest income elasticities but the lowest degree of increasing returns



such as high-tech sectors for middle and high-income countries, can trigger a process of cumulative causation of increasing growth rates. On the other hand, an intervention in favour of sectors with lower Verdoorn coefficients and income elasticities than the average initiates a process of cumulative causation with decreasing growth rates. Finally, an intervention in sectors with lower Verdoorn coefficients and higher income elasticities than the average (or vice-versa) may produce both results (increasing and decreasing growth rates) depending on the parameters.

4.5 Specific simulations based on estimated values

In the last section, four theoretical cases were simulated to evaluate the consequences for growth of the intervention in sectors with different income elasticities and Verdoorn coefficients. Here, values for these parameter estimated in the latter chapters are applied to simulate the consequences of countries' specialisations in different industries[95].

The sectoral division is the same as the latter chapters, which is based on the categories of demand. Sectors are grouped into natural-resources-based products [NR], consumption goods [CG] and capital goods [KG]. Estimations for these sectors' elasticities and increasing returns, as resumed in Table 4.1, shows that capital goods has the highest income elasticities of demand for exports and imports, and a high Verdoorn coefficient for middle- and high-income countries. Consumption goods, on the other hand, have the lowest Verdoorn coefficient for middle- and high-income countries, and its incomes elasticities are around the average. Finally, natural-resource-based products have the lowest income elasticities, but this sector's Verdoorn coefficient is similar to capital goods (for middle-income countries it is slightly higher). Based on these values, the long-term impact of a structural change in favour of each of this group of sectors is simulated.

Table 4.1: Parameters adopted in the simulations based on estimated values

	Sim 5	Sim 6	Sim 7	Estimated Values*
b_{NR}	0.60	0.60	0.60	0.60 (Ch. 3)
b_{CG}	0.20	0.20	0.20	0.20 (Ch. 3)
b_{KG}	0.50	0.50	0.50	0.50 (Ch. 3)
$\varepsilon_{NR} = \pi_{NR}$	1.8	1.8	1.8	1.47-2.63 (Ch. 2)
$\varepsilon_{CG} = \pi_{CG}$	2.4	2.4	2.4	1.19-3.56 (Ch. 2)
$\varepsilon_{KG} = \pi_{KG}$	3.0	3.0	3.0	1.73-4.81 (Ch. 2)
z	4.0%	4.0%	4.0%	
$\varphi_{NR} = b_{NR}/2$	0.26	0.26	0.26	
$\varphi_{CG} = b_{CG}/2$	0.15	0.15	0.15	
$\varphi_{KG} = b_{KG}/2$	0.25	0.25	0.25	
$\sigma_{NR} = \sigma_{CG} = \sigma_{KG}$	0.005	0.006	0.015	
$\phi_{NR} = \phi_{CG} = \phi_{KG}$	1.5	1.5	1.5	
$\omega_{X_{NR}} = \omega_{M_{NR}}$	30%	30%	30%	
$\omega_{X_{CG}} = \omega_{M_{CG}}$	40%	40%	40%	
$\omega_{X_{KG}} = \omega_{M_{KG}}$	30%	30%	30%	

(*) Simulations are based on the results obtained in the latter chapters. Estimation of Verdoorn's coefficient is based System GMM panel model for countries with US$ 10,000 of GDP per capita (middle-income countries) controlling for human capital and technological gap. Estimation of income elasticities are based on long panel models (DOLS and GLS) for South American and South/East Asian countries.

Before proceeding with these simulations, however, the sectoral growth rates for

[95] These estimations are consistent with those found by other sectoral studies. For elasticities of demand see, for example, Gouvea and Lima (2010, 2013), and for the degree of increasing returns, see Angeriz *et al.* (2009).

those sectors that are not under intervention must be defined, once equation (4.10) is only valid for two-sector models. By using same *rationale* of equation (4.11), which is important to keep sectoral output growth consistent with income elasticities of demand, and the idea that the growth of other sectors adjusts to keep total output growth constant, sectoral growth rates of the other sectors are defined as:

$$y_2 = \frac{\pi_2^*}{\omega_2\pi_2^* + \omega_3\pi_3^*}(\bar{y} - \omega_1\bar{y_1}) \tag{4.41}$$

and

$$y_3 = \frac{\pi_3^*}{\omega_2\pi_2^* + \omega_3\pi_3^*}(\bar{y} - \omega_1\bar{y_1}) \tag{4.42}$$

where sector 1 is the one under intervention, and sectors 2 and 3 are the other sectors.

4.5.1 Specialisation in capital goods

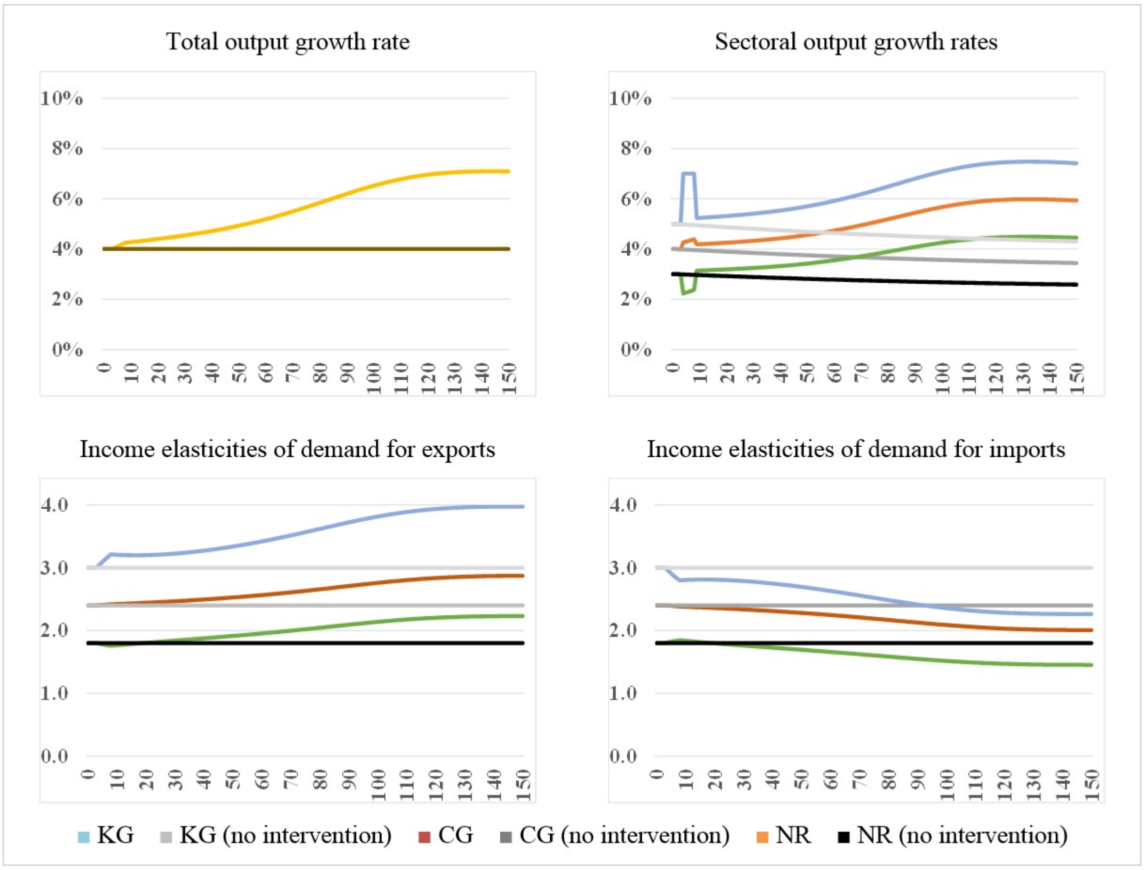
The sector of capital goods presents the highest income elasticities of exports and imports and the Verdoorn coefficient higher than the average. Thereby, as we can see from Figure 4.5, a structural change in favour of this sector will promote a faster growth of the economy as a whole in the long term, even if, at first, the growth of economy keeps unchanged.

Similar to Simulation 1, a faster growth of capital goods relative to the others sectors during a five-period period has a permanent impact on the economic growth rate. Because this sector presents the highest income elasticities of demand and a relatively high degree of increasing returns (or Verdoorn coefficient), a positive impact on the sector increases the elasticities faster than the decrease of the elasticities of the others sectors, and thus the weighted elasticities ratio is positively affected. An increase on the weighted elasticities ratio, in turn, promotes an increase in the actual rate of growth.

As can be seen from the graph, after the intervention, all sectors are growing faster than without any intervention[96]. Hence, although the intervention, at first, has a negative impact on the other sectors' elasticities of exports and a positive impact on import elasticities, a faster growth of these sectors after the period of intervention

[96]Intervention is assumed to change sectoral growth rates, such as presented in the upper-right graph of Figure 4.5. However, because faster growth rates affects variables in level, sectoral share on total GDP also changes. The intervention considered in this section, for example, increases the growth rate of capital goods from 5% to 7% during five periods, whilst it reduces the growth rates of other sectors. Consequently, the share of capital goods in GDP increases from 30% to 33%.

Figure 4.5: Simulation 5: impact of an intervention in favour of capital goods



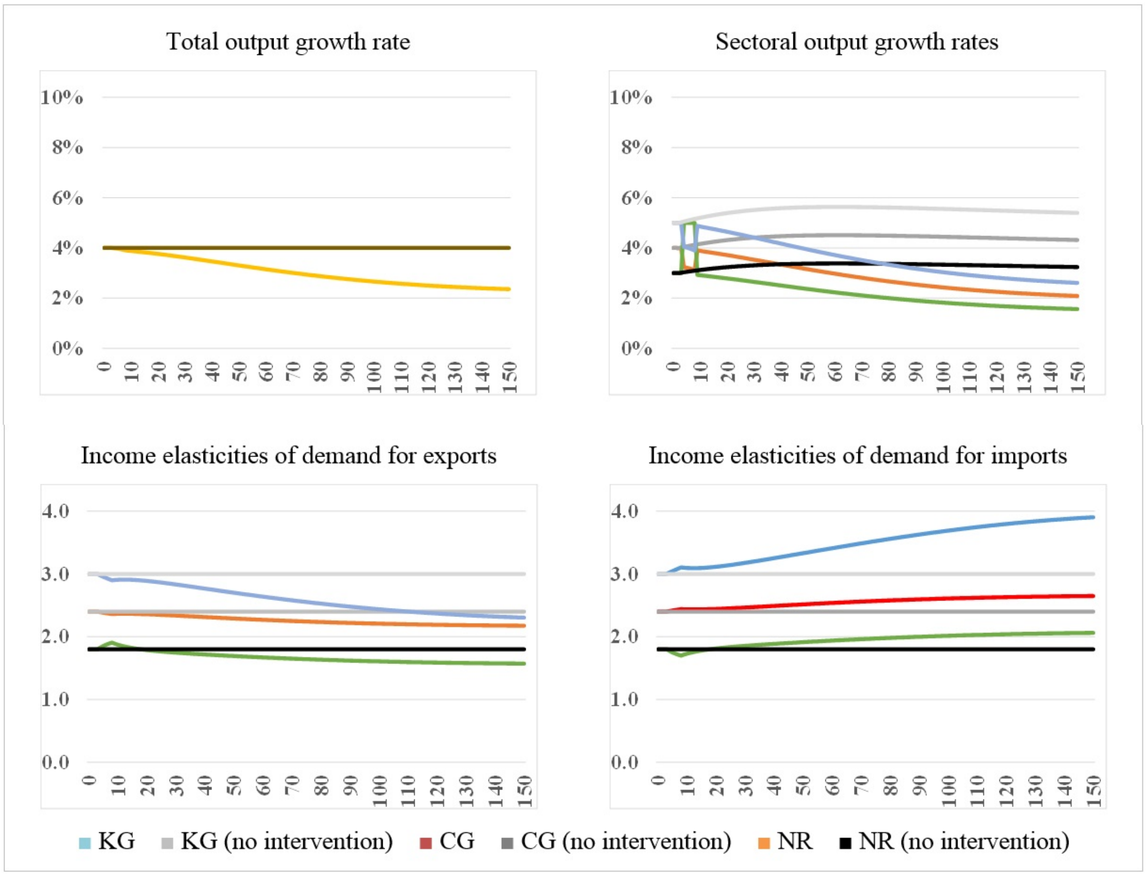
increases its own elasticities of exports and decreases its own elasticities of imports, which also contributes to a faster economic growth. Thereby, not only the capital goods sector will grow faster, but the economy as a whole, and hence the intervention will imply on a faster growth of all sectors, triggering a cumulative process of increasing growth output rates.

4.5.2 Specialisation in natural resources

The production of natural resources presents the highest Verdoorn coefficient for middle-income countries, but this sector has the lowest income elasticities of exports and imports. Consequently, as shown in Figure 4.6, a structural change in favour of this sector triggers a process of decreasing growth rates.

On the one hand, an intervention in favour in favour of this sector promotes, at first, an increase in its own elasticities of demand for exports and a decrease in its own elasticities of demand for imports. On the other hand, once the rate of growth

Figure 4.6: Simulation 6: impact of an intervention in favour of natural resources



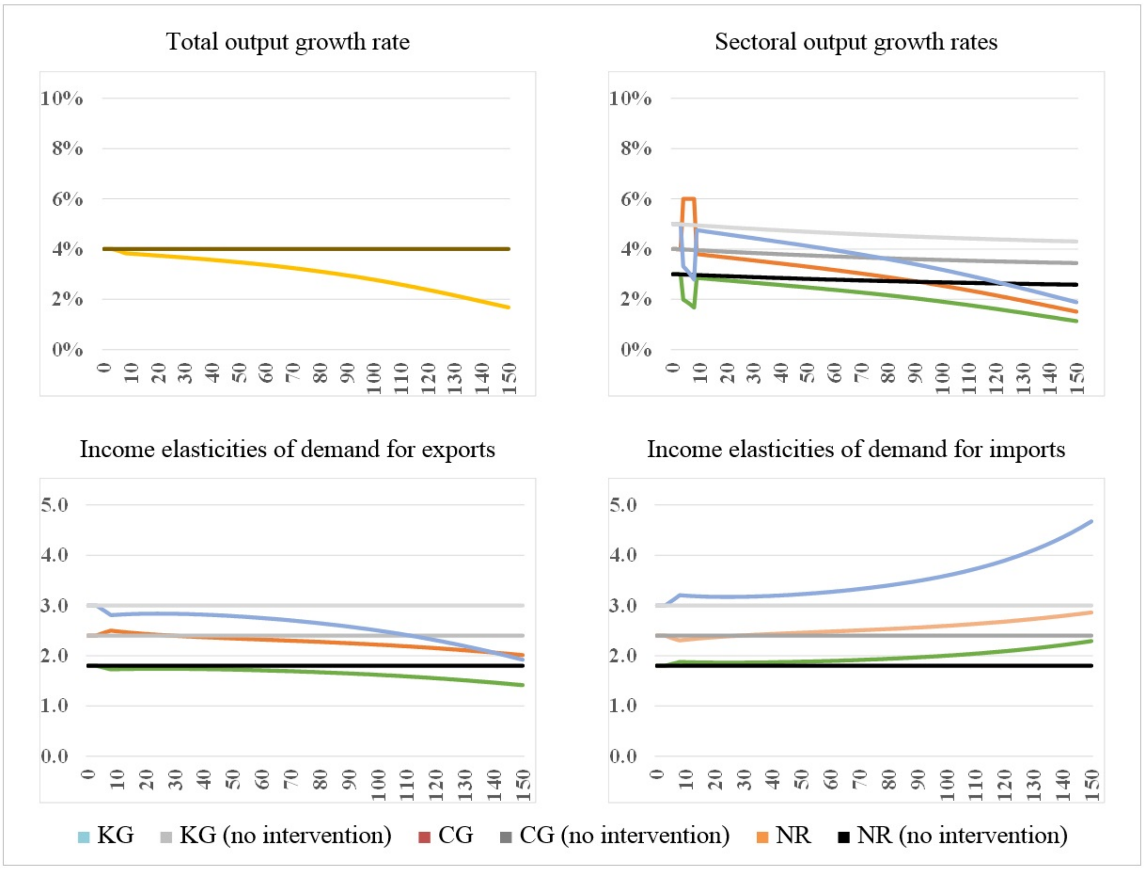
of capital and consumption goods decreases, the elasticities of demand for exports of these sectors decrease and the elasticities for imports increase. Because the Verdoorn coefficient of natural-resource-based products is the highest, the former effect is more important than the latter, which would suggest an increase in the weighted elasticities ratio. However, the share of natural-resources-based products in total exports is increasing, and the share in total imports is decreasing. Because this sector has the lowest elasticities, the weighted elasticity ratio is negatively affected, and hence economic growth rate decreases due to a fall in the BPCG rate.

A lower economic growth in all sectors (including in natural-resource-based products) after the period of intervention promotes a decrease in all sectors' elasticities of demand for exports, as well as an increase in their elasticities of demand for imports. Therefore, the country's growth rate falls continually due to a fall in the weighted elasticities ratio, characterising a process of cumulative causation with negative impacts for this country. Essentially, the case of natural-resource-based products shows that it is not enough to stimulate a sector that has the highest Verdoorn coefficient. Despite being important to promote a faster growth of the sector that is able to increase productivity the most, an intervention in favour of natural resources decreases the weighted elasticity ratio, affecting negatively growth rates in the long term.

4.5.3 Specialization in consumption goods

Although consumption goods present income elasticities of demand for exports and imports higher than the average, the consequences of a structural change in favour of this sector does not imply a faster growth rate of the economy. Because this sector has the lowest Verdoorn coefficient, an increase in the growth rate of consumption goods (to the detriment of the others sectors) will promote decreasing growth rates, as shown in Figure 4.7.

Figure 4.7: Simulation 7: impact of an intervention in favour of consumption goods



An intervention capable of increasing consumption goods' growth rate (to the detriment of others sectors growth rates) promotes an increase in its own elasticities of exports and a decrease in its own elasticities of imports. However, it also promotes a decrease in the elasticities of exports and an increase in the elasticities of imports of the others sectors. During the period of intervention, the impact on the weights of the elasticities must be positive to promote an increase in countries' BPCG rate. However, because consumption goods have the lowest Verdoorn coefficient, the increase in its elasticity of exports (and the decrease in its elasticity of imports) is compensated for by the fall in the elasticities of exports of the other sectors (and the growth of elasticities of imports), such as presented in Figure 4.7. Consequently, a structural change towards consumption goods negatively affects the BPCG rate, which implies a slow growth rate, triggering a negative process of cumulative causation.

4.6 Concluding remarks

Although the process of structural change is at the root of Kaldor's explanation for economic growth, many Kaldorian models do not incorporate it directly and, consequently, they are unable to present a complete explanation for the origin of the cumulative causation processes. Setterfield (2011), for example, presented a model that shows a possible mechanism behind the growth rate divergence across countries. His model, however, does not explain how structural changes can trigger a process of cumulative causation, because it is not constructed in a multisectoral framework. According to this model, a country that is achieving a faster growth rate due to an increase in demand for agriculture products, for example, will achieve a faster and an increasing growth rate, even if the manufacturing sector is shrinking. Despite providing an interesting approach for the existence of cumulative causation in a BPCG model, Setterfield's approach is unable to show the importance of sectoral specificities for long-term growth because it does not incorporate a structural analysis.

On the other hand, the Kaldorian models constructed in a multisectoral framework, despite providing insights about the relevance of sectoral specificities for long-term growth, are unable to show how the interaction between these specificities is important in triggering a cumulative causation process. The multisectoral version of Thirlwall's law, for example, shows the importance of structural composition of exports and imports to explain countries' growth rate divergence. However, this model does not incorporate endogenous technological change and its impacts on these elasticities, and hence it does not show the interaction between these two sectoral characteristics.

In this chapter, the process of economic growth and cumulative causation were understood from a sectoral perspective. The main conclusion is that the divergence in countries' growth rates can be explained by the sectoral structure of countries' production and trade because sectors have different income elasticities of demand for exports and imports, such as presented in the multisectoral version of Thirlwall's law, and different degrees of increasing returns, such as presented by the Verdoorn's law. On the one hand, an intervention in favour of sectors with the highest income elasticities of demand and the highest Verdoorn coefficient promotes a faster and an increasing economic growth (even if, at first, total output growth rate is not affected). On the other hand, specialisation in sectors that present the lowest Verdoorn coefficient and the lowest elasticities promotes a reduction in countries' growth rates. Finally, if the specialisation takes place in sectors with a high Verdoorn coefficient but with low elasticities (or vice-versa) the result is not conclusive: it depends on the relative size of these parameters.

Assuming the parameters obtained in the last two chapters for the sectoral income elasticities of demand for import and export and for the Verdoorn coefficient, it was seen that specialisation in capital goods and high-tech sectors is important to promote a faster economic growth in the long term for middle- and high-income countries. Because these sectors present the highest income elasticities and high Verdoorn coefficients for these countries, promoting a structural change towards them can trigger a cumulative process where the faster growth of output of these sectors increases productivity, which increases income elasticities of exports and decreases income elasticities of imports. Consequently, because economic growth is ultimately determined by the balance-of-payments constraint, specialisation in these sectors promotes a faster growth of the economy as a whole, which increases productivity and non-price competitiveness of all sectors.

Therefore, a structural approach for the explanation of a cumulative causation is essential to understanding economic growth in the long term. Although a general approach for countries' growth divergence can provide important insights, some relevant features only can be seen from a sectoral perspective, with special regards for the origin of this cumulative causation processes.

Chapter 5

Impacts of increase in trade on countries' sectoral structure of production and trade: a structural decomposition analysis

5.1 Introduction

The process of increase in trade, which has resulted to some extent from the trade liberalization that took place in developing countries during the 1990s and 2000s, had significant impacts on world production chains. From a global perspective, these countries were integrated into global supply chains, which permitted an increase in exports that had not been witnessed in decades. On the other hand, these changes may have resulted in the substitution of imported inputs for domestic suppliers. As a result, the potential for growth in demand to precipitate economic growth may have declined, provided that domestic absorption of demand has fallen.

To analyse the consequences of this complex process, a relevant aspect that should be taken into account is identifying which sectors have changed more substantially and what implications this has on economic growth. On the one hand, in Asian economies, the growth in the last two decades was led by the increase of high-tech exports. On the other hand, in Brazil and other natural resource exporters, the wealth effect of primary product exports was one of the most important variables in the recent economic growth. An economic growth led by primary sectors, however, may result in a relevant constraint for economic growth in the long run. Although one can argue that expansion based on the production and export of primary goods did not have a negative effect on the economy, there is a large (and growing) literature that is attempting to show the limitations of promoting growth based on these sectors.

As discussed in the first four chapters, many mechanisms could explain why promoting structural changes towards specific sectors (according to countries' stage of development) is an important source of growth. Two of these mechanisms are especially relevant to the analysis that follows. First, because some sectors present higher income elasticities of demand for exports and imports, specialising in them is essential to avoid balance-of-payments constraints. Second, because some sectors present higher degrees of dynamic increasing returns (and it determines sectoral productivity growth rates), specialising in them is essential to explain overall productivity (and thus competitiveness) growth.

Chapter 4 showed how a process of cumulative causation (and its consequences for countries' long-term growth rates) can be understood through the interaction of these two channels. Moreover, Chapter 4 pointed out which sectors can trigger a cumulative causation process of increasing growth rates: capital goods and high-tech industries. Hence, specialising in them is likely to promote a faster economic growth in the long term.

In this context, to understand the effects of increase in trade on economic growth, one should analyse its effects on countries' sectoral structure of production and trade. In this chapter, such enquire is addressed through a Structural Decomposition Analysis, which evince the impact of changes in the structure of demand and supply on each sector's output.

Structural decomposition analysis (SDA) considers that shifts in total output essentially depend on changes in final demand and intermediate consumption. Changes in final demand affect the total output directly, and because intermediate consumption depends on input-output coefficients, total output is also affected by shifts in them. In this study, we develop a method for decomposing the changes in intermediate consumption into two parts: technological change and substitution of imported inputs. The aim of this decomposition is to identify to what extent substitution between domestic and imported inputs affects output growth across sectors. This analytical tool is relevant to providing a detailed investigation of the consequences of changes in countries' supply chains on their structure of production and trade.

Furthermore, analysing the decomposition of changes in industrial chains is also important to determine those sectors in which the substitution of imported inputs for domestic inputs is more intense and those in which export growth has compensated for the negative impacts on output. By using the analytical tool developed in this chapter, it is possible to compare the negative effects of the substitution between domestic and imported inputs and its positive effects on export growth across sectors and countries.

In addition to this introduction, this chapter has five other sections. Section 2 discusses the process of trade liberalization in developing countries during the 1990s and 2000s. Section 3 discusses the evolution and limitations of SDA, as well as its applications in Brazil. In section 4, this method is extended to incorporate the substitution between national inputs and imports. Section 5 applies this analytical tool to the Brazilian data and compares the results with the contribution of exports to evaluate the net impacts on output of the substitution between national inputs and imports. This analytical tool is also applied to other economies, with the aim of comparing Brazil with other countries. Finally, Section 6 discusses the relevance and limitations of the proposed approach and provides the concluding remarks.

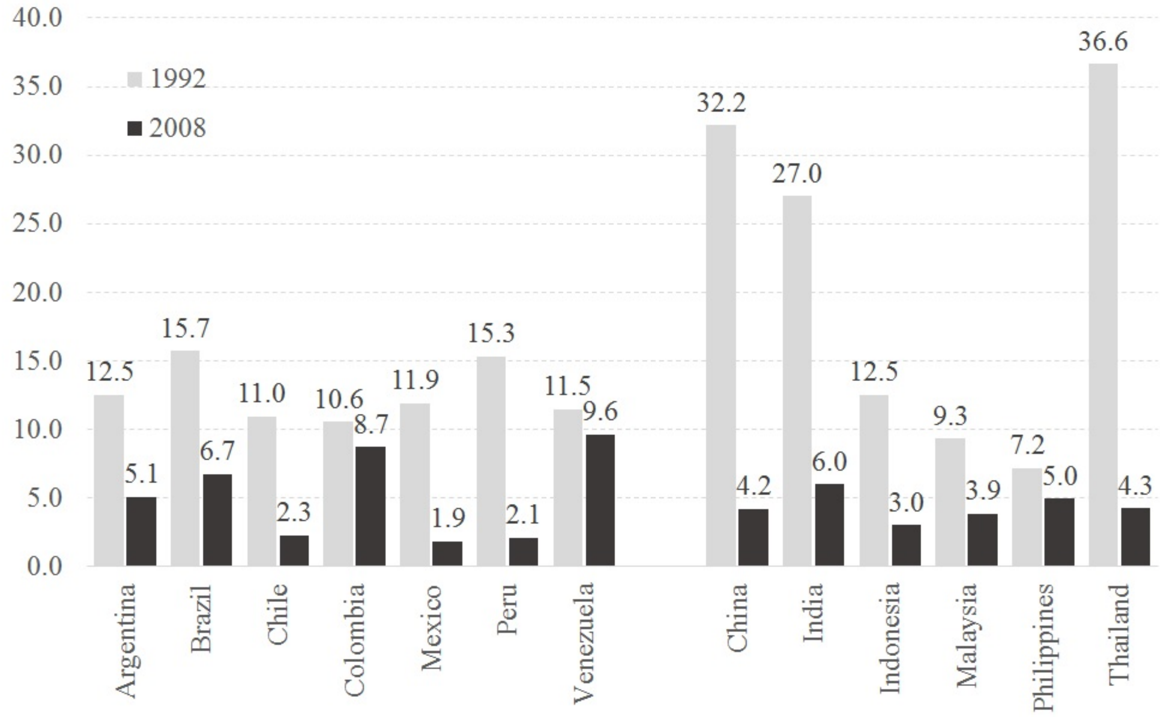
5.2 Trade liberalization and the growth in inter-country commerce

Since the 1990s, international commerce has been increasing significantly in developing countries. A relevant issue that cannot be ignored is the removal of tariff and non-tariff trade barriers. Based on the argument that free trade is the best trade policy to promote countries' development – and that protectionism is responsible for some developing countries' low growth rates – multilateral trade agreements, such as the North American Free Trade Agreement (NAFTA) and the Asia-Pacific Economic Cooperation (APEC), as well as many bilateral agreements, have promoted inter-country commerce through trade liberalisation.

Among the most important trade barriers are import tariffs. These tariffs were widely used to promote specific sectors, and the removal of these tariffs has become one of the main target of trade agreements under the system of the World Trade Organization (WTO). Besides reducing trade, and the hence the benefits of countries' specialisation in those goods for which they have comparative advantages, these tariffs are argued to damage countries' competitiveness, once the protected sectors are less stimulated to compete and innovate. Consequently, as presented in Figure 5.1, effectively applied import tariffs, considering both preferential and bound tariffs, have been reduced for all the largest developing economies between the early 1990s and the late 2000s.

*

Figure 5.1: Effectively applied import tariff (%), weighted average (1992-2008)



Data for 1992 and 2008 for those countries they are available. For those countries data are not available in these years, the closest year is presented. For Argentina, Indonesia and Malaysia, data for 1993 are presented, rather than 1992; for Mexico, 1991; and, for the Philippines, 1998. For Indonesia, rather than 2008, data for 2007 is presented.
Source: World Integrated Trade Solution (WITS)

The average effectively applied import tariffs have been reduced in all Latin American countries to less than 10% in the late 2000s. In most of these countries, this reduction was greater than 7.0 p.p. between 1992 and 2008. In Brazil, for example, the average tariff has been reduced by 8.1 p.p., while in Argentina it has dropped by 7.5 p.p., and, in Chile, Mexico and Peru, effective tariffs have been reduced by 9.0, 10.3 and 13.1 p.p. respectively. In South and East Asia, the reduction of these tariffs were even more significant. In China, Thailand and India, average import tariffs were greater than 25% in the early 1990s, but they have been reduced to 3.9%, 4.8% and 6.9%, respectively. In Indonesia, Malaysia and the Philippines, although the level of import tariffs was lower than other developing countries, the average of these tariffs have been reduced to 4.0% or less. Data for other developing countries, such as Russia, South Africa and Turkey, shows the same trend. The Average import tariff has dropped from 11.3% to 8.6% in Russia, from 6.1% to 2.0% in Turkey, and, in South Africa, it has been reduced by 9.6 p.p., from 13.5% to 3.9%.

Besides the cut or complete removal of import tariffs, many other trade barriers, such as import quotas and regulatory legislation, have been also removed to promote trade liberalisation under the argument that they protect uncompetitive sectors. All these measures have resulted in increasing trade between countries. According to WB-WDI, trade has increased in almost every country. In Brazil, it has increased from 15.2% of GDP in 1990 to a peak of 27.1% in 2008, in Argentina it has increased from 15.0% to 36.7% in the same period, and, in Mexico, from 38.3% to 58.1%. The same trend is verified in South and East Asian countries. In China, for example, between 1990 and 2008, trade has increased from 26.7% of GDP to 62.3%; in India it was only 15.2% of GDP and reached 52.2% in 2008. Thereby, the last two decades were marked as a period of decreasing trade barriers as part of a process of trade liberalisation and increasing inter-country commerce.

Reduction or removal of import tariffs was not a sector-specific process. Instead, it was a generalised process ranging from raw materials to sophisticated goods, such as Chemicals and Machinery. Even though there are few exceptions, import tariffs have dropped for all countries in almost every sector, as presented in Table 5.1.

Import tariffs for raw materials, which were lower than the average in the early 1990s, have been reduced or completely removed in all the largest developing countries but Russia. In Brazil, for example, the average tariff in this sector was 8.7% in 1992 and it has dropped by 8.2 p.p. to 0.5%, in 2008. Similarly, import tariffs in raw materials have been almost completely removed in Argentina, Mexico, China, Indonesia, Thailand and South Africa. In Russia, it has increased from 10.0% in the early 1990s to 11.3% in 2008.

In Textiles, import tariffs were significantly higher than the average in the early 1990s. In all countries but Turkey, it was greater than 10%, and, in some extraordinary cases, such as Thailand, it was almost 100%. Even though they remain relatively high when they are compared to other sectors, these tariffs have dropped in the vast majority of countries (the exceptions were Brazil and Russia).

In Chemical, similarly to raw materials, import tariffs were relatively low in the

Table 5.1: Effectively applied import tariff (%), selected sectors (1992-2008)*

	Raw Materials		Textiles		Chemicals		Mach/Transp	
	1992	2008	1992	2008	1992	2008	1992	2008
Latin America								
Argentina	3.7%	0.3%	15.8%	15.2%	7.7%	5.2%	14.7%	5.6%
Brazil	8.7%	0.5%	13.8%	18.9%	13.4%	5.2%	25.9%	10.2%
Chile	11.0%	2.6%	11.0%	3.9%	11.0%	1.3%	10.9%	2.2%
Colombia	9.1%	9.9%	16.2%	14.0%	7.7%	5.9%	11.2%	10.7%
Mexico	5.4%	0.6%	15.7%	7.2%	9.8%	0.6%	13.7%	1.9%
Peru	15.2%	1.3%	19.2%	10.8%	15.0%	2.2%	15.2%	1.8%
Venezuela	8.8%	6.0%	12.0%	8.3%	8.8%	7.1%	13.0%	10.1%
South and East Asia (developing)								
China	8.6%	1.4%	61.7%	14.7%	22.2%	5.5%	34.0%	5.3%
India	3.9%	4.8%	41.2%	13.5%	58.4%	6.4%	51.6%	6.6%
Indonesia	4.8%	1.0%	13.9%	3.5%	8.5%	3.1%	16.3%	3.4%
Malaysia	8.4%	4.4%	16.4%	6.3%	9.5%	2.6%	8.5%	1.8%
Philippines	8.7%	3.6%	13.1%	7.5%	5.9%	3.2%	4.3%	3.1%
Thailand	45.9%	1.0%	95.6%	7.9%	39.0%	3.8%	34.9%	6.4%
Other developing countries								
Russia	10.0%	11.3%	13.8%	14.8%	9.3%	8.6%	11.2%	8.1%
South Africa	2.9%	0.4%	38.6%	25.0%	8.0%	2.1%	15.2%	4.9%
Turkey	6.4%	2.3%	6.7%	3.1%	5.1%	1.2%	5.1%	0.7%

(*) Data for 1992 and 2008 for those countries they are available. For those countries data are not available in these years, the closest year is presented. For Argentina, Indonesia, Malaysia, South Africa and Turkey, data for 1993 are presented, rather than 1992; for Mexico, 1991; for Russia, 1997; and, for the Philippines, 1998. For Indonesia, rather than 2008, data for 2007 is presented.

Source: World Integrated Trade Solution (WITS)

early 1990s and they have dropped to less than 7% in all the largest developing economies but Russia. In Brazil, China and India, they have been significantly reduced from more than 13% in the early 1990s to around 6% in 2008. In Mexico, Chile, Peru, Malaysia, Turkey and South Africa, imports tariffs for chemical products have been reduced to less than 3% in 2008.

Although import tariffs vary significantly among countries in Machinery and Transport Equipment, they have been significantly reduced in all the largest developing economies. In the early 1990s, they ranged from 4.3% in the Philippines to 51.2% in India. After almost two decades of trade liberalisation, these tariffs have been reduced to less than 11% in all these economies. In Brazil, for example, they dropped from 25.9% to 10.2%, in China, from 34.0% to 5.3%, and, in India, from 51.6% to 6.6%.

Therefore, import tariff reduction was a process that took place in almost every sector in developing countries. With few exceptions, such as the textile industry in Brazil and raw materials in Russia, import tariffs have dropped significantly from the early 1990s to the late 2000s as one of the most important policies in the process of commerce liberalisation.

Despite being a generalised process, the consequences of this trade liberalisation are far from being homogeneous across countries and sectors. In some countries, such as China, Malaysia and Thailand, imports of high-tech goods has increased in parallel with the growth of exports, whereas exports of primary products has dropped as a percentage of total exports. On the other hand, in Latin American countries, exports of primary products have increased significantly, whilst the share of high-tech exports has become stagnated or decreased. Considering that sectors have different potential to promote high and sustained growth rates in the long term, as discussed in the former chapters, it is important to analyse the consequences of growth in trade and trade liberalisation to countries' sectoral structure of trade and production. This analysis is crucial to understand what countries are benefiting the most of this process, as well as to evaluate how the others could benefit more.

5.3 Theoretical and empirical background of SDA

Leontief (1936, 1941) was the first to conduct an economic structural analysis by using input-output (I-O) methods. Following his work, this method has been widely used in such analyses and to study the effects of economic conditions on political outcomes, e.g., through the use of backward and forward linkages (Hirschman, 1958; 1968) and through the decomposition of sectoral deviations from proportional expansion (Chenery *et al.*, 1962). Nevertheless, the use of decomposition methods to analyse the sources of structural changes was only introduced in the 1970s by Skolka's inaugural paper (Skolka, 1977).

Many studies have applied this methodology in different countries, such as Feldman, McClain, and Palmer (1987) in the United States, and Skolka (1989) in Austria. Feldman, McClain, and Palmer (1987) decomposed industry output changes in the United States in 1963 and 1978 into changes in final demand (level and mix of products) and in input-output coefficients. Alternatively, Skolka (1989) analysed the composition of net output in terms of the contributions of technological shifts, domestic final demand, foreign trade, and labour productivity.

In the 1980s and 1990s, SDA methods became an important analytical tool in structural studies, and different methods were developed. As a result, Rose and Casler (1996) and Dietzenbacher and Los (1998) developed critiques of the methodology. Rose and Casler (1996) described the fundamental principles behind alternative SDA methods, whereas Dietzenbacher and Los (1998) discussed the problems caused by the application of different SDA methods.

Despite being used widely to understand structural changes in different economies, changes in input-output coefficients are usually interpreted as technological changes in SDA applications[97]. However, these coefficients may also change due to the substitution between domestic and imported inputs, which cannot be taken into account without an extension of the SDA method.

Based on Chenery *et al.* (1962)'s decomposition of sectoral deviation from proportional expansion, Pamukçu and de Boer (1999) have proposed a primary extension for the SDA method to evaluate the demand that was not absorbed domestically as a consequence of substitution between domestic suppliers and imports in different sectors.

In the case of the Brazilian economy, Guilhoto *et al.* (2001) decomposed the changes in economic structure between 1959 and 1980 and compared them with those in the United States. The authors confirmed prior findings regarding the role of changes in final demand in determining the growth rate of sectoral output in Brazil during the 1960s and 1970s. Kupfer *et al.* (2003) decomposed the Brazilian employment growth based on I-O tables for the years 1990, 1996 and 2001. According to the authors, between 1990 and 1996, imports were responsible for a significant decrease in employment, and exports were not able to compensate the negative impact. From 1996 to 2001, however, the result was the converse: exports have affected employment positively, compensating the negative impact of import growth.

More recently, Messa (2012) and Moreira and Ribeiro (2012) applied SDA methods to Brazilian data to decompose structural changes in the 2000s. Although Messa (2012) showed that a decline in the intermediate consumption of domestic industrial output

[97]In SDA, technological changes mean changes in the input-output coefficients, which do not necessarily impact on total technological growth (in the Solow or growth accounting sense of the term). According to Rose and Casler (1996:42), "In nearly all SDA formulations, changes in the structural matrix are ascribed to a nebulous 'technological change', which is often broadly interpreted to include any factor that causes a change in a technical (structural) coefficient, such as true technological change, technical substitution (response input price changes) and scale effects."

is the most important determinant of the growth differential between services and industry, the author did not decompose the changes in input coefficients into technical change and domestic supply substitution. Moreover, Moreira and Ribeiro (2012) did a similar analysis and concluded that output growth was primarily explained by changes in final demand, whereas technical progress (measured by input coefficients) had less of an impact.

Thus far, however, studies have failed to account for the effect of substitution between domestic suppliers and imports on output. Therefore, an analytical decomposition of recent Brazilian growth in comparison with other economies is necessary to verify the extent to which this country has been achieving low growth rates as a result of substitution between imported and domestic inputs in sectors that have the potential to increase the country's growth rate. From a structuralist perspective, this approach is crucial to understand why countries' growth rates may decline or increase in the long run.

5.4 Incorporating imported inputs into SDA

Initially, the changes in gross output by sector are decomposed into impacts of final demand growth and changes in Leontief coefficients (the coefficients of direct and indirect inputs). The SDA method is applied following Miller and Blair's (2009) approach. Considering the basic Leontief model for two distinct years (0 and 1), the vector of gross output x in year $t = 0, 1$ is given by:

$$x^1 = L^1 f^1 \tag{5.1}$$

and

$$x^0 = L^0 f^0 \tag{5.2}$$

where L is the Leontief matrix of direct and indirect production coefficients, and f is the vector of final demand. Thus, the observed change in gross output is:

$$\Delta x = x^1 - x^0 = L^1 f^1 - L^0 f^0 \tag{5.3}$$

Some possible rearrangements may be applied to decompose the changes in L and f, and their effects on Δx. Two alternative methods are presented:

$$\Delta x = L^1(f^0 + \Delta f) - (L^1 - \Delta)f^0 = (\Delta L)f^0 + L^1(\Delta f) \tag{5.4}$$

$$\Delta x = (L^0 + \Delta L)f^1 - L^1(f^1 - \Delta f) = (\Delta L)f^1 + L^0(\Delta f) \tag{5.5}$$

Here, the focus will be on the average approach of these two methods. According to Dietzenbacher and Los (1998), this approach is often an acceptable method for SDA. Summing equations (5.4) and (5.5)

$$2\Delta x = (\Delta L)f^0 + L^1(\Delta f) + (\Delta L)f^1 + L^0(\Delta f) \tag{5.6}$$

and averaging gives:

$$\Delta x = \frac{1}{2}(\Delta L)(f^0 + f^1) + \frac{1}{2}(L^0 + L^1)(\Delta f) \tag{5.7}$$

where the first term refers to the effects of the change in the Leontief coefficients over the change in gross output, and the second term refers to the effects of the change in final demand.

Thereafter, the changes in Leontief coefficients have to be divided into technological changes and substitution between national and imported inputs. Given $L^1 = (I - A^{D1})$ and $L^0 = (I - A^{D0})$, where A^D is the national direct coefficients matrix, post-multiply L^1 through by $(I - A^{D1})$

$$L^1(I - A^{D1}) = I = L^1 - L^1A^{D1} \tag{5.8}$$

and pre-multiply L^0 through by $I - A^{D0}$

$$(I - A^{D0})L^0 = I = L^0 - A^{D0}L^0 \tag{5.9}$$

Rearrange (5.8) and post-multiply by L^0

$$L^1 - I = L^1A^{D1} \Rightarrow L^1L^0 - L^0 = L^1A^{D1}L^0 \tag{5.10}$$

Similarly, rearrange (5.9) and pre-multiply by L^1

$$L^0 - I = A^{D0}L^0 \Rightarrow L^1L^0 - L^1 = L^1A^{D0}L^0 \tag{5.11}$$

Subtract (5.11) from (5.10)

$$\Delta L = L^1 A^{D1} L^0 - L^1 A^{D0} L^0 = L^1(\Delta A^D) L^0 = L^1(A^{D1} - A^{D0}) L^0 \tag{5.12}$$

Because A^D is the difference between the total direct coefficient matrix (A) and the direct coefficient matrix of imported goods (A^M), the change in the Leontief matrix can be written alternatively as

$$\Delta L = L^1[(A^1 - A^M 1) - (A^0 - A^{M0})] L^0 \tag{5.13}$$

Rearranging, the decomposition of changes in the Leontief matrix into technological changes and substitution between national and imported goods is given by

$$\Delta L = L^1(\Delta A) L^0 + L^1(-\Delta A^M) L^0 \tag{5.14}$$

where the first term is the contribution of the changes in total direct coefficients (technological change) to changes in the Leontief coefficient, and the second term is the contribution of changes in imported direct coefficients (substitution of national inputs).

Finally, substituting (5.14) in (5.7), the total output growth can be divided into the contribution of (i) technological change, (ii) substitution between national inputs and imports, and (iii) final demand growth:

$$\Delta x = \underbrace{\frac{1}{2}[L^1(\Delta A) L^0](f^0 + f^1)}_{(i)} + \underbrace{\frac{1}{2}[L^1(-\Delta A^M) L^0](f^0 + f^1)}_{(ii)} + \underbrace{\frac{1}{2}(L^0 + L^1)(\Delta f)}_{(iii)} \tag{5.15}$$

5.5 Results

5.5.1 Application of the analytical tool in Brazil

The method developed in this study was applied to Brazilian data from 1995 to 2008 and to a set of comparison countries[98]. The data are available at the World Input-Output Database (WIOD) (Timmer, 2012). The database covers most of the major world economies (including Brazil) in the period between 1995 and 2008, and the data are available in both current and previous years' prices. Thus, changes in prices

[98] The World International Input-Output Database (WIOD) presents data from 1995 to 2009. However, the last year may present relevant distortions due to the crisis and it was thus excluded from the analysis to avoid bias in the results.

and quantities may be analysed separately, which reduces bias caused by volatility in exchange rates and relative price changes.

Before conducting the SDA, all tables were deflated as follows:

$$a_{i,j}^{t(p1995)} = a_{i,j}^{t(pyp)} \prod_{t=1995}^{t-1} \frac{a_{i,j}^{t(pyp)}}{a_{i,j}^{t(cyp)}} \tag{5.16}$$

where $a_{i,j}$ is the output of sector i used as input by sector j, t is the table year, $p1995$ stands for base year prices (1995), pyp stands for previous year prices, and cyp stands for current year prices.

The same method was applied to obtain the changes from 1995 to 2008, which means that 1995 is the base year for all results. Table 5.2 presents the main findings for Brazil. Essentially, it shows, in real terms, the impact of each factor (technological change, substitution of national inputs and final demand) on sectoral output. The total impact, given by the last column is the sum of the impact of each factor[99].

Table 5.2: Decomposition of the Brazilian output growth (1995-2008)

	Techn. change impact	Subst. of national inputs	Final demand growth	Total output growth
Total	9.3%	-8.2%	44.9%	46.0%
Agriculture and Mining	24.0%	-16.3%	62.2%	70.0%
Manufacturing	5.7%	-14.9%	43.0%	33.7%
Low Tech	-1.1%	-8.4%	35.0%	25.4%
Med/High Tech	18.8%	-27.5%	58.5%	49.7%
Chemicals	26.4%	-32.1%	32.3%	26.7%
Machinery	3.4%	-13.6%	81.5%	71.2%
Electrical	33.8%	-44.9%	33.1%	22.0%
Transport	6.3%	-15.5%	94.1%	85.0%
Services	9.8%	-3.9%	44.3%	50.2%

Authors' elaboration based on WIOD.

The data in Table 5.2 allow assessing the relevance of the decomposition of changes in the Leontief coefficient into changes in technology and substitution of imported inputs for domestic inputs. For the economy as a whole, nearly all of the positive effects

[99] Because the aim of this chapter is to analyse the impact of increase in trade on productive chains, the impact on the substitution between national and foreign final demand is not considered. An increase in trade could have affected negatively the growth in final demand. However, it goes beyond the aim of this chapter, and hence it is not calculated.

of changes in technology on total output were offset by the increase in imported inputs. Although the final demand growth had an impact of 44.9% on total output (97.6% of the total 46.0% output growth in the period 1995-2008), the inclusion of substitution between imported and domestic inputs permitted by the SDA method allowed us to conclude that technological change also had a relevant impact on output (9.3%). However, this impact was compensated for by the increase in import coefficients (-8.2%), and thus changes in input coefficients (which is given by the sum of the impact of substitution for imported inputs and technological change) had limited effects on total output.

Moreover, the analysis of total output was significantly influenced by the results in the service sector. Because the inputs of this sector were predominately domestic, the substitution impact on output was limited to 3.9%. If the substitution effect in the other sectors were considered, the results would be more relevant. In the primary sectors (agriculture and mining), the impact of the substitution of imported inputs on output was 22.6%, which means that the impact of technological change in these sectors was offset by the increase of imports.

The most important results, however, were observed in the high- and medium-high-technology manufacturing sectors, in which the effects of technological change had an impact of 15.1% on output growth. Nevertheless, the substitution of imported inputs compensated for these effects: it reduced the overall output growth by 16.3%, and the effects were particularly pronounced in the chemicals and electrical/optical equipment sectors, in which the negative impact was 32.1% and 44.9%, respectively.

More relevant insights may be extracted from the results through an analysis of the effects from a historical perspective. Table 5.3 presents the results according to three distinct periods in Brazilian macroeconomic policies: 1995 to 1999, 1999 to 2003, and 2003 to 2008.

Between 1995 and 1999, there were relevant substitutions of imported inputs for national inputs in high- and medium-high-technology manufacturing. This substitution had a negative impact of 4.5% on total output. During these years, the Plano Real was adopted to reduce inflation. This was based on the reduction of tariffs with the aim of opening the economy to imported goods, as well as on real exchange rate appreciation. As a result, the production chains of the most innovative and technologically advanced sectors were significantly affected.

Table 5.3: Impact of the substitution of national inputs on total output

	1995-1999	1999-2003	2003-2008	1995-2008
Total	-0.4%	-0.2%	-7.2%	-8.2%
Agriculture and Mining	1.8%	-0.9%	-13.7%	-16.3%
Manufacturing	-1.5%	-0.1%	-12.6%	-14.9%
Low Tech	0.0%	0.4%	-8.6%	-8.4%
Med/High Tech	-4.5%	-1.0%	-20.5%	-27.5%
Chemicals	-3.8%	-0.3%	-27.7%	-32.1%
Machinery	-1.4%	-1.0%	-10.0%	-13.6%
Electrical	-8.3%	-3.8%	-34.0%	-44.9%
Transport	-3.4%	0.4%	-9.6%	-15.5%
Services	-0.1%	-0.1%	-3.8%	-3.9%

Authors' elaboration based on WIOD.

In contrast with this period, from 1999 to 2003 the Brazilian economy experienced a period of subsequent balance-of-payments crisis and exchange rate depreciation. The inflation target regime was implemented with the aim of controlling inflation; thus, high interest rates were necessary to maintain the capital inflows and control demand growth. As a consequence, although the substitution of imported inputs had not significantly affected the output growth, Brazilian growth rates were very low.

The process of substitution between imported and national inputs picked up between 2003 and 2008. For the economy as a whole, the increase of imported inputs decreased the total output by 7.2% during these five years. Again, high-tech sectors were the most affected. Their total output was 20.5% lower owing to the increase in imported inputs. In the chemical and electrical sectors, the impact on total output was 27.7% and 34.0%, respectively.

This period, however, was characterized by high real exchange rate appreciation and high growth rates. Thus, the net impact of the substitution was very ambiguous. On the one hand, it reduced the positive impacts of final demand growth on total output by 7.2%. On the other hand, it may have been essential to the increase of the final demand effects, assuming it may be relevant to reduce costs and increase exports.

Therefore, it was important to consider that despite contributing negatively to the total output, the process of substitution was not necessarily negative. The positive results for primary sectors suggested that the increase in exports in these sectors was related to the substitution of imported inputs, as a result of reducing prices. In the following section, we identify those sectors in which the growth of exports compensated for the negative impact of the domestic input substitution, in order to assess the net impact of the substitution.

5.5.2 The net impact of exports and the substitution of imports for national inputs

To evaluate the impact on economic growth of the substitution between imports and domestic suppliers, we analyse the contribution of exports. As previously mentioned, this substitution may have reduced economic growth because the final demand is not absorbed by domestic suppliers. However, it may have increased exports, assuming it reduced the costs of production and increased the quality of goods. Thereby, we analyse its net impact to evaluate the real consequences of this substitution on output.

Starting from equation (5.7), final demand is divided into (*i*) the contribution of domestic final demand and (*ii*) the contribution of exports:

$$\Delta x = \frac{1}{2}(\Delta L)(f^0 + f^1) + \underbrace{\frac{1}{2}(L^0 + L^1)(\Delta f^D)}_{(ii)} + \underbrace{\frac{1}{2}(L^0 + L^1)(\Delta f^E)}_{(ii)} \tag{5.17}$$

where Δf^E is the vector of export growth, and Δf^D is the vector of domestic final demand growth.

The contribution of exports to output growth can be divided into two parts: the direct contribution of the analysed sector export growth and the indirect contribution of other sectors' export growth to the analysed sector output growth[100], which is given by the difference between the total contribution and the direct contribution. Table 5.4 presents a comparison between the contribution of export growth and the substitution of imported inputs on output.

The results show that despite being neutral for the economy as a whole, the net impact of the substitution of domestic suppliers had ambiguous effects when considering the sectors separately. The impacts were positive for some sectors, such as agriculture and mining, but they were negative for others, such as chemicals and electrical/optical equipment.

The last two columns of Table 3 show the positive contribution of export growth (direct and indirect) and the negative contribution of the substitution of imported inputs. From these data, we can conclude that high-tech sectors were the most affected

[100] The indirect impact considers, for example, the impact of car exports on tire output growth. Because car production indirectly demands tires, car export growth increases the production of tires.

Table 5.4: Impact of exports on output growth (1995-2008)

	Impact of exports growth			Substitution of
	Direct	Indirect	Total	national inputs
Total	5.4%	5.2%	10.5%	-8.2%
Agriculture and Mining	21.7%	13.0%	34.6%	-16.3%
Manufacturing	9.7%	6.2%	15.9%	-14.9%
Low Tech	7.8%	5.9%	13.7%	-8.4%
Med/High Tech	13.5%	6.7%	20.2%	-27.5%
Chemicals	2.7%	7.5%	10.1%	-32.1%
Machinery	15.3%	4.6%	19.9%	-13.6%
Electrical	8.8%	5.2%	14.0%	-44.9%
Transport	27.4%	8.4%	35.8%	-15.5%
Services	1.5%	3.9%	5.4%	-3.9%

Authors' elaboration based on WIOD.

by the substitution. Between 1995 and 2008, the substitution of imported inputs for national suppliers contributed negatively to agriculture and mining and to high-tech sectors output growth by 16.3% and 27.5%, respectively. However, export growth had a 36.4% contribution to agriculture and mining, whereas its contribution to high-tech sectors was only 20.2%. Thus, although the direct impact of the substitution (not considering exports) was negative for agriculture and mining, the net contribution of this substitution process was negative only for high-tech sectors.

Analysing the high-tech sectors, some other relevant results can be seen from Table 3. The net results were negative for chemical products and electrical (low contribution of exports to growth *vis-à-vis* high contribution of substitution of imports for domestic suppliers). However, the results were positive for machinery and transport equipment.

Exports contributed 19.9% (15.3% directly and 4.6% indirectly) to the machinery sector output growth, whereas the output decreased by 13.6% due to the substitution of domestic inputs. The transport sector showed even better results. Exports increased the output by 33.8% (27.4% directly and 8.4% indirectly), whereas the negative direct impact of the substitution of national suppliers was only 15.5%.

These results bring an important issue to the debate on industrial policies. The Brazilian National Development Bank (BNDES) provides many benefits for national producers of machinery and transport equipment, such as funding with very low interest rates[101] and certain benefits to stimulate exports (especially for producers that

[101] Because Brazilian financial markets provide funding with high interest rates, BNDES funding with low interest rates is a key factor in the growth of these sectors.

use domestic inputs). Furthermore, the two Brazilian industrial plans launched in the 2000s (PITCE and PDP) focused on these sectors, providing many tax reductions and other benefits to promote exports[102]. Thus, although high-tech sectors were the most affected by the increase in imported inputs, within this group, those sectors that Brazilian industrial policies have mainly focused on were the ones that took advantage of the substitution process and received a positive net contribution.

5.5.3 Comparison between Brazil and other economies

The substitution of imported inputs for domestic suppliers has been an important aspect of Brazilian output growth in the last two decades, especially in highly technological sectors. However, it is necessary to evaluate this process in comparison with other economies to understand whether Brazil may be characterised as a special case or, alternatively, whether it is merely following a worldwide trend.

The methodology developed in Section 4 was applied to four developing countries (Brazil, China, India and Mexico) and to the three biggest developed countries (Germany, Japan, and United States) and South Korea. The results for the developing countries are presented in Table 5.5, and those for the developed countries in Table 5.6.

Table 5.5: Impact of exports and the substitution between imported and national inputs on output (1995-2008), developing countries

	Brazil		China		India		Mexico	
	Subst.	Exp.	Subst.	Exp.	Subst.	Exp.	Subst.	Exp.
Total	-8.2%	10.5%	-56.8%	202.1%	-17.0%	40.4%	-12.4%	31.4%
Agric./Mining	-16.3%	34.6%	-55.0%	62.4%	-17.4%	16.1%	-16.9%	19.8%
Manufacturing	-14.9%	15.9%	-72.4%	310.4%	-27.6%	58.6%	-25.2%	68.5%
Low Tech	-8.4%	13.7%	-35.3%	209.2%	-26.8%	54.2%	-13.7%	23.4%
Med/High Tech	-27.5%	20.2%	-149.7%	521.3%	-29.4%	69.4%	-42.8%	137.4%
Chemicals	-32.1%	10.1%	-104.0%	229.7%	-38.9%	67.2%	-37.2%	16.1%
Machinery	-13.6%	19.9%	-92.3%	329.4%	-18.2%	49.1%	-2.1%	83.3%
Electrical	-44.9%	14.0%	-294.1%	1031.6%	-67.1%	165.3%	-78.6%	286.1%
Transport	-15.5%	35.8%	-42.1%	346.0%	-15.0%	51.5%	-22.5%	117.8%
Services	-3.9%	5.4%	-34.9%	108.3%	-6.7%	33.3%	-2.9%	8.2%

Subst.: Impact of substitution of national inputs on output; Exp.: Impact of export growth on output.
Authors' elaboration based on WIOD.

Considering these four countries, it is possible to conclude that developing eco-

[102]For a brief review of these industrial plans and the BNDES policies for machinery and transport equipment, see Magacho (2012).

nomies have experienced a process of increasing imported inputs, which negatively affected almost every sector. China was the most affected by this process (its output was 56.8% lower due to the substitution for domestic suppliers), corroborating the hypothesis that its industrial chains were strongly integrated into global supply chains during the analysed period.

However, as previously suggested, the results were analysed considering also the positive impacts of export growth. The data on China indicate that the contribution of exports compensated for the decrease caused by the substitution of imports for domestic inputs. Considering the economy as a whole, the net contribution was high. The export growth increased the output by 202.1%, whereas the substitution of imports decreased the output by 56.8%. The net contribution was relatively neutral only for agriculture and mining. In these sectors, exports increased the output by 62.4%, but the substitution for domestic inputs decreased the output by 55.0%.

Similar results were verified for the other developing countries, but at a lower scale. The export growth in Mexico compensated for the negative contribution of the substitution for domestic suppliers in all analysed sectors. In India, it happened in all other sectors than agriculture and mining. In this sector, the export growth was not enough to compensate for the negative impact of substitution for domestic suppliers. Furthermore, although the substitution for domestic suppliers decreased the output of high-tech sectors in Mexico and India by 42.8% and 26.8%, respectively, the net impact was positive, in contrast to the results in these sectors in Brazil.

Thereby, Brazil and India were the only analysed countries in which some sectors were affected positively and others negatively by the substitution. Nevertheless, although in India mining and agriculture were the negatively affected sectors, in Brazil the high-tech sectors were the ones that received a negative contribution from the net impact of the substitution of imports for domestic inputs.

To complement this analysis, the contribution of exports and of the substitution between imported inputs and national suppliers to the output growth of developed countries is shown in Table 5.6.

The results for the developed countries show that the negative impact of the substitution of national suppliers was compensated for by the positive impact of export growth. Although the difference between the positive and the negative impacts was not substantial for the United States and Japan, it was very positive for Germany

Table 5.6: Impact of exports and the substitution between imported and national inputs on output (1995-2008) – developed countries

	South Korea		USA		Japan		Germany	
	Subst.	Exp.	Subst.	Exp.	Subst.	Exp.	Subst.	Exp.
Total	-4.1%	93.4%	-5.4%	9.5%	-3.9%	13.7%	-7.0%	33.0%
Agric./Mining	-69.9%	9.5%	-44.8%	5.9%	-61.5%	4.8%	-31.1%	23.3%
Manufacturing	1.7%	172.4%	-9.5%	19.8%	-4.6%	30.8%	-12.0%	63.3%
Low Tech	-3.3%	56.3%	-8.2%	9.0%	-4.1%	13.1%	-9.9%	43.2%
Med/High Tech	7.3%	305.1%	-10.9%	33.0%	-5.2%	51.6%	-14.0%	84.0%
Chemicals	5.5%	116.5%	-17.2%	16.0%	-6.1%	20.0%	-14.2%	70.8%
Machinery	2.1%	137.2%	-10.5%	18.5%	-2.7%	30.7%	-9.3%	61.8%
Electrical	17.5%	584.7%	-11.4%	66.6%	-7.4%	76.3%	-22.6%	111.5%
Transport	-2.1%	175.8%	-6.2%	21.0%	-3.8%	57.9%	-11.0%	90.1%
Services	-3.8%	28.1%	-2.4%	5.8%	-1.7%	5.2%	-3.7%	17.9%

Subst.: Impact of substitution of national inputs on output; Exp.: Impact of export growth on output.
Authors' elaboration based on WIOD.

and South Korea. The substitution of imported inputs impacted negatively on the output of Germany by 7.0%, and the output of Korea by 4.1%. However, exports increased the output by 33.0% and 93.4%, respectively, indicating that, similarly to China, Germany and Korea strongly benefited from the substitution.

Analysing the sectors separately yielded very similar results to those found in India. Only mining and agriculture did not present a positive net impact in all the developed countries analysed. In all other sectors, especially the high-tech ones, exports impacted positively on output and compensated for the negative impact of the growth in imported inputs.

5.6 Concluding remarks

This study analysed the sources of Brazilian growth during the 2000s in comparison with other economies. The impacts of changes in countries' production structures and in demand absorption were investigated through structural decomposition analysis (SDA). Although this method has been widely applied to understanding the contribution of particular sources of demand to countries' growth patterns, these applications have not considered the substitution between domestic suppliers and imports. Thus, the SDA method is extended to provide a detailed investigation of the sources of national growth from a sectoral perspective because this substitution may have important consequences for long-term economic growth.

The empirical investigation suggests that the substitution of imported for national inputs is a key factor in SDA, assuming that the impact of technological change is underestimated if this substitution is not taken into account. Therefore, the extension of SDA in this chapter is very relevant to analysing structural changes in countries' production chains.

From the results presented in this chapter, it is possible to verify that production is significantly more fragmented in the late 2000s than in the early 1990s. All the countries analysed presented the substitution of imported inputs for domestic suppliers, and this fact was verified in almost every sector.

The substitution process, however, had positive impacts in many sectors in most of the countries studied, despite having negative impacts in some cases. The net impact for Brazil (considering also the impact of export growth in the sectoral output) was positive for mining and agriculture but was negative for high-tech sectors, especially for chemicals and electrical equipment. In the other countries analysed, only the agriculture and mining sectors were negatively affected, whereas positive impacts were seen in all other sectors.

Thus, in Brazil, the potential for growth in demand to precipitate economic growth has declined in the most technologically advanced sectors but has increased in agriculture and mining, whereas the exact opposite is true in the other countries studied. Thereby, an important constraint to Brazil's long-term growth has emerged in the past decades, assuming that high-tech sectors are the ones that present higher increasing returns to scale, higher positive spillovers in production, and higher potential to boost productivity growth.

Finally, our findings show that China, India, Korea, and Germany were the countries most positively affected by the substitution. Although the substitution of imports for domestic suppliers contributed negatively to economic growth, this effect was significantly compensated for by the increase in exports in all sectors other than mining and agriculture. The results suggest that these countries benefited the most from the integration of global supply chains, whereas Brazil's high-tech production sector was not able to take advantage of the process.

The findings in this study have to be analysed while considering that the sectoral structure of production and exports is relevant to explaining the long-term growth rates of countries. Taking into account the findings of the previous chapter of this work, which stressed the importance of high-tech and capital good industries for promoting sustainable growth rates through a cumulative causation process, we conclude that Brazil's specialization in agriculture and mining contributes negatively to the country's economic growth. On the other hand, the specialization of China and India in high-tech activities is positive for these countries because it is important to reduce the productivity gap with the most advanced economies.

Chapter 6

Structural Decomposition of Vertical Specialisation and Domestic Content of Exports

6.1 Introduction

In recent decades, countries' structures of production and trade have been significantly changing due to the increasing vertical specialisation of production processes. As part of Global Value Chains (GVC), rather than exchanging finished goods produced domestically, countries are increasingly trading intermediate inputs and specialising production in specific tasks. The UNCTAD (2013) annual report has estimated that, in the 2000s, value-added trade contributed almost one fifth of developed countries' GDP and almost one third of developing countries' GDP.

According to Hummels *et al.* (1998), three aspects characterise this process of vertical specialisation: goods are produced in multiple sequential stages; two or more countries specialise in producing some, but not all, stages; and at least one stage crosses an international border more than once. Essentially, vertical specialisation is the process in which a country uses imported inputs to produce goods it later exports.

There are many explanations for this process of fragmentation in the production systems. Baldwin (2013), for example, argued that the information and communications technology (ICT) revolution made it possible to coordinate complex systems of production at distance, and the vast wage differential between countries made it profitable for firms. Furthermore, the reduction of trade and communication costs have increased the possibility of firms to specialise production in countries according to their comparative advantages.

There is little controversy about the positive impacts of engaging in vertical specialisation from the perspective of firms. As stressed by many authors, such as Gereffi *et al.* (2005), increasing fragmentation is an important source of competitiveness, as the increasing trade costs are compensated by cost reductions and increasing specialisation in their core activities. Thereby, they argue that multinational companies find it advantageous to "outsource" an increasing share of their non-core activities domestically and abroad. Pietrobelli and Rabellotti (2011), in the same line, argue that for firms in developing countries integrating in GVC besides providing new markets for their products plays a very important role in accessing knowledge and enhancing learning activities.

When it comes to countries, however, fragmentation of production has a wide range of positive and negative aspects. On the one hand, the benefits for firms extends to countries in the sense that cost reduction and specialisation in firm's core activities increases productivity, and hence countries' competitiveness in external markets. Moreover, because integration into GVC increases countries' access to technologies developed abroad, the process of internalisation of knowledge is stimulated domestically.

On the other hand, fragmentation of production may cause many irreversible damages for countries' systems of innovation. Pisano and Shih (2009) argue that the US has been losing their innovation potential once they are outsourcing industrial activities. By transferring activities to other countries, American companies have lost the industrial commons (the collective operational capabilities that underpin new product and process development in the industrial sector), and hence the US has lost the capacity to develop high-tech products and the expertise to produce the most advanced technologies embodied in new products. Furthermore, according to Berger (2013) and Lundvall (1992), proximity to systems of innovation, markets and suppliers is essential to develop new technologies, once the interaction between producers and users is at the root of the learning process. Thereby, critical strengths and capabilities that help the development of new products and process have been lost, as industrial ecosystems have disappeared.

Moreover, a critical aspect on the benefits and costs of engaging in vertical specialisation is related to sectoral specialisation. As discussed in the latter chapters, sectors present different potential to promote high and sustained growth rates in the long term due to their specificities. The negative impact of outsourcing production in sectors that present high dynamic increasing returns to scale, for example, is greater than outsourcing sectors that present constant returns to scale, once, in the former sectors, technological progress is induced by output growth. Thereby, rather than discussing benefits and costs of engaging in vertical specialisation for the economy as a whole, this chapter discusses to what extent the increase in sectoral vertical specialisation has promoted an increase in countries' sectoral market share. Essentially, although vertical specialisation has a negative effect by reducing the domestic content of countries' exports due to outsourcing, it has a positive effect as countries' competitiveness increases and it reflects in gains in world market share. The net impact of this process is analysed in the level of productive chains through a structural decomposition analysis of countries' vertical specialisation and domestic content of exports.

In order to proceed with this analysis, the impact of vertical specialisation and the domestic content of exports is decomposed as twofold: (1) the impact of the increase of imported inputs on the value added in production chains, and (2) the impact of exports growth. The net impact is the difference between these impacts, and it can be interpreted as the impact of production fragmentation on the capacity of sectoral exports to increase the value added embodied in these exports. The net impacts for each production chain is thus compared to other countries in order to evaluate what are those sectoral chains that contributed the most for each country growth.

This chapter is divided into six sections besides this introduction. Section 2 discusses the process of trade liberalisation in developing countries during the 1990s and 2000s. The following section estimates degree of Vertical Specialisation (VS) based on Hummels *et al.* (2001) for some developing and developed countries. In Section 4 this approach is extended by assuming Vertical Integrated Sectors (Pasinetti, 1973) to obtain a measure of vertical specialisation by productive chains rather than for the economy as a whole. Section 5 presents and discusses the methodology employed to decompose the impact of fragmentation on the degree of vertical specialisation and the domestic content of exports. Section 6 applies this methodology and presents the results for the same countries analysed before. Finally, in the last section, the concluding remarks are presented.

6.2 Vertical Specialisation across countries

Hummels *el al.* (2001) define vertical specialisation as the "increasing interconnection of production processes in a vertical trade chain that stretches across many countries, with each one specialising in particular stages of a good's production sequence". This concept brings the notion that fragmentation of production process is related to the increase of imported inputs in countries exports, and, as a direct consequence, to the decrease of domestic content in their exports. With the aim of estimating to what extent this process has taken place in different countries, the authors use input-output matrices to measure the degree of Vertical Specialisation (VS).

The approach adopted by the authors focuses on a specific feature of this process: imported intermediate goods are used to produce other goods, which are themselves exported to another country. VS, in this sense, takes place once a good is produced in two or more sequential stages in different countries and this good (which can be a finished or an intermediate good) is exported rather than consumed domestically.

Initially, the authors focused on the direct imported inputs, defining the degree of vertical specialisation as follow:

$$VS_k = \iota' A^M f^E \tag{6.1}$$

where VS is vertical specialisation for country k, ι' is the transposed column-vector of ones, A^M is the matrix of direct imported technical coefficients, and f^E is the column-vector of exports by sector. VS is the total imported input content of exports or, equivalently, foreign value-added embodied in exports. By dividing VS_k by total exports, the $VS_k\, share\, of\, exports$ is obtained, as follows:

$$VS_k\, share\, of\, exports = \iota' A^M f^E (\iota' f^E)^{-1} \tag{6.2}$$

This result presents the degree of VS of a given country. However, it is only taking into account direct imported inputs. Because domestic inputs also embody imported inputs, VS has to be extended to consider direct and indirect imported inputs in order to measure the total foreign value-added embodied in exports.

Defining L^M as the matrix of direct and indirect imported inputs, obtained through:

$$L^M = A^M (I - A^D)^{-1} \tag{6.3}$$

where I is the identity matrix and A^D is the matrix of domestic technical coefficients, VS_k and $VS_k\, share\, of\, exports$ can be re-written as follow:

$$VS_k = \iota' L^M f^E \tag{6.4}$$

and

$$VS_k\, share\, of\, exports = \iota' L^M f^E (\iota' f^E)^{-1} \tag{6.5}$$

These changes are important to measure the degree of VS among countries by considering the imported inputs used in the last stage of transformation and all the intermediate goods embodied in the intermediate stages of production. Table 6.1 presents the result for the degree of VS for a group of selected countries for some years between 1995 and 2008.

Table 6.1: Vertical Specialisation as a share of total exports (1995 USD prices)

	1995	1999	2003	2008	Δ 1995-2008
Brazil	7.9%	8.6%	9.5%	18.8%	10.9 p.p.
China	16.0%	17.7%	26.2%	38.2%	22.2 p.p.
India	10.5%	12.4%	14.3%	24.0%	13.5 p.p.
Mexico	26.2%	38.5%	42.6%	42.6%	16.4 p.p.
South Korea	24.2%	21.7%	20.6%	25.0%	0.9 p.p.
Germany	17.9%	19.1%	20.8%	25.2%	7.3 p.p.
Japan	6.5%	6.6%	7.2%	11.5%	5 p.p.
United States	10.3%	11.2%	10.7%	13.7%	3.5 p.p.
Simple average	14.9%	17.0%	19.0%	24.9%	10 p.p.

Authors' elaboration based on WIOD.

As can be seen from the table, developing countries' degree of VS has significantly increased during this period, indicating that their production is increasingly more fragmented. China, India and Mexico presented the highest increase in the degree of VS, ranging from an increase by 13.5 p.p. in the Indian case to 22.8 p.p. in China. Moreover, the table shows that more advanced countries presented the lowest increase in the degree of VS during this period. For some countries, such as South Korea and Germany, it happened because the value was already high in 1995. In the case of Japan and US, however, the degree of VS was low in 1995 and it has not increased significantly, resulting in a low level of fragmentation in 2008.

Furthermore, it is possible to see that China, Mexico, South Korea and Germany have engaged more in this process than the others, and presented high values for VS in 2008. In the case of China and Mexico, the imported content of exports is greater than 35%, and in the case of South Korea and Germany it is around 25%. In contrast with these economies, Brazil, Japan and the US present the lowest degree of fragmentation. In Brazil, direct and indirect imported inputs represents 18.8% of exports, whilst in Japan and the US, this value is lower than 15%.

6.3 Differences in Vertical Specialisation among sectors

The approach employed in the last section allowed us to evaluate to what extend countries are increasingly engaging in fragmentation processes. However, such as discussed before, a very important issue to understanding the benefits and costs of this vertical specialisation process is its sectoral impacts. Because some sectors are more important than others to promote high and sustained growth rates, the analysis of fragmentation cannot be limited to the measure of the degree of VS for the economy as a whole. It is crucial to measure VS in the sectoral level to provide a more detailed assessment of the consequences of these fragmentation processes.

The notion of Vertically Integrated Sectors, developed by Pasinetti (1973), is employed here to analyse fragmentation processes sectorally. Essentially, rather than considering sectoral output or value added as their production, in this approach, it is assumed that the economy only produces finished goods, and intermediate goods used in the process of production are components of these finished goods[103]. This notion is important because rather than focusing on the goods themselves, the focus of analysis moves towards production chains. In this sense, it is possible to analyse the direct and indirect imported inputs embodied in each of these Vertically Integrated Sectors. Thus, Sectoral VS can be written as:

$$VS_{ki} = \iota' L^M \hat{f^E} \mu_i \tag{6.6}$$

where $\hat{f^E}$ is the diagonalised vector of exports in which the main diagonal is equal to the vector of exports and the others elements are zero, and μ_i is a column-vector in which the element(s) corresponding to the analysed sector(s) is(are) one and the others are zero.

Analogously to the procedure adopted in (6.2) and (6.5), the sectoral degree of VS, or the $VS_{ki}\, share\, of\, exports$ can be obtained by dividing the result of equation (6.6) by the total exports of the analysed sector(s), as follows:

$$VS_{ki}\, share\, of\, exports = \iota' L^M \hat{f^E} \mu_i (\iota' \hat{f^E} \mu_i)^{-1} \tag{6.7}$$

Table 6.2 presents the results for developing countries for the starting year (1995)

[103] In the case of exports of intermediate goods, they are assumed as finished goods, once they will not be subject to any process of transformation in the country under consideration after exported.

and the last year under consideration (2008). For the economy as whole, as expected, the results are the same as before, once μ_i is a column-vector of ones, and thus $f^E = \hat{f^E}\mu_i$. Nevertheless, the sectoral outcomes show that this analysis is very important. They show that fragmentation of specific chains does not follow the same trend as the whole economy, as well as that some chains are significantly more integrated into GVC than others.

Table 6.2: Sectoral VS as a share of exports (1995 USD prices), developing countries

	Brazil		China		India		Mexico	
	1995	2008	1995	2008	1995	2008	1995	2008
Total	7.9%	18.8%	16.0%	38.2%	10.5%	24.0%	26.2%	42.6%
Primary Sectors	5.7%	15.9%	7.1%	32.8%	3.2%	7.0%	5.6%	10.3%
Agriculture	4.3%	10.8%	5.8%	17.0%	2.7%	4.7%	8.5%	15.5%
Mining	7.9%	22.4%	9.3%	55.1%	5.8%	11.6%	4.5%	9.1%
Manufacturing	9.0%	22.5%	17.6%	39.4%	12.3%	29.8%	35.4%	49.2%
Low Tech	8.2%	19.0%	16.2%	26.9%	11.7%	34.1%	21.4%	31.8%
Med/High Tech	10.8%	28.0%	20.5%	45.7%	14.4%	21.5%	42.0%	53.2%
Chemicals	9.9%	31.0%	15.4%	55.2%	15.8%	26.9%	12.9%	21.9%
Machinery	9.3%	20.5%	14.9%	30.7%	15.4%	21.2%	30.7%	55.9%
Electrical	13.1%	37.0%	22.3%	49.9%	10.9%	17.7%	54.4%	61.1%
Transport	11.4%	27.0%	16.3%	28.1%	13.4%	20.7%	34.8%	42.2%
Services	4.0%	7.2%	9.8%	30.3%	6.3%	10.0%	7.5%	11.5%

Authors' elaboration based on WIOD.

The first important result from this table is that the degree of vertical specialisation has increased in every sector, indicating that the process of production fragmentation is generalised rather than specific to countries or sectors. However, some sectors are significantly more integrated into GVC than others. Manufacturing is the most fragmented sector, with special regards to high-tech industries. Among developing countries, Brazil is the one whose manufacturing exports have the lowest share of imported inputs. Although manufacturing VS share of exports in Brazil has increased from 9.0% to 22.9%, this value is significantly lower than for the other developing economies. China and Mexico, on the other hand, present the highest degrees of VS in manufacturing. In China, imported inputs accounted for 39.4% of exports in 2008, while, in Mexico, they accounted for almost half of manufacturing exports.

The comparison between Brazil and India brings another important issue to the debate on the importance of a sectoral approach. Whilst low-tech industries are those with the highest degree of VS in India (in 2008, imported inputs accounted for 32.9% of exports), in Brazil, high-tech industries are those with the highest degree of fragmentation, with special regards to chemicals and electrical. In the case of chemicals, the Brazilian degree of VS is greater than India and Mexico, and it has increased by 21.1 p.p. between 1995 and 2008. Moreover, relatively to other countries, transport equipment industry is also very fragmented in Brazil. The degree of VS in this industry is similar to China and significantly greater than the India's transport industry. Thereby, it is clear that even though the Brazilian manufacturing is not as integrated in GVC as other developing countries, it is a specific characteristic of low-tech manufacturing, once high-tech industries present degrees of VS similar to Mexico and India and, in transport equipment, similar to China.

Finally, by analysing primary sectors, the outcomes are, again, significantly different from the finding for the economy as a whole. Although the fragmentation in these sectors is lower than the total for every country, in Brazil and China, mining presents a relatively high degree of VS. In India and Mexico, the share of imported inputs in mining is 11.6% and 9.1%, respectively, whilst in Brazil, it is 22.4%, and, in China, 55.1%.

Comparing these findings for developing countries with more advanced economies, many other important results can be obtained. Table 6.3 presents the sectoral VS as a share of exports for developed countries. In contrast to the results obtained for developing economies, in all developed countries, low-tech industries are more fragmented than high-tech industries. In Korea, where the production is the most fragmented among developed economies, low-tech exports embodied 64.7% of imported inputs in 2008, whilst high-tech industries embodied only 20.0%. In the other developed countries, despite lower differences, the trend is the same: in contrast to developing countries, in Germany, Japan and the US, the share of imported inputs embodied in high-tech exports is lower than in low-tech exports.

Furthermore, in all these four countries, the increase in fragmentation was lower than it was for developing economies, with special regards to high-tech industries. Between 1995 and 2008, the degree of VS in high-tech industries has increased by 7.8 p.p. in Germany, by 3.3 p.p. in Japan, and only by 0.5 p.p. in the U.S. In the Korean case, there were a reduction of the degree of VS in high-tech activities from 26.2% to 20.0%, led by the electrical sector: the imported inputs embodied in Korean electrical exports has dropped from 28.1% to 15.0%.

From these results, it is possible to conclude that focusing only on the findings for the economy as a whole is not enough to analyse the fragmentation process that took

Table 6.3: Sectoral VS as a share of exports (1995 USD prices), developed countries

	South Korea		Germany		Japan		United States	
	1995	2008	1995	2008	1995	2008	1995	2008
Total	24.2%	25.0%	17.9%	25.2%	6.5%	11.5%	10.3%	13.7%
Primary Sectors	9.5%	11.6%	10.9%	15.3%	13.1%	28.2%	6.9%	15.6%
Agriculture	9.6%	12.3%	11.3%	15.2%	5.2%	7.2%	7.2%	13.0%
Mining	9.2%	16.8%	10.3%	16.0%	16.1%	38.3%	6.1%	28.4%
Manufacturing	27.1%	25.1%	19.2%	27.7%	6.9%	12.2%	14.1%	17.8%
Low Tech	28.6%	64.7%	19.1%	29.3%	8.7%	25.0%	11.9%	25.8%
Med/High Tech	26.2%	20.0%	19.2%	27.0%	6.5%	9.8%	15.1%	15.6%
Chemicals	27.0%	42.3%	17.7%	24.5%	6.9%	19.2%	11.7%	25.8%
Machinery	24.0%	26.4%	17.0%	27.3%	6.3%	9.8%	12.9%	21.1%
Electrical	28.1%	15.0%	19.0%	22.4%	6.9%	7.5%	15.8%	8.6%
Transport	22.1%	30.5%	22.2%	32.6%	5.8%	11.4%	17.5%	23.4%
Services	12.1%	24.4%	7.3%	10.1%	4.3%	6.6%	3.3%	5.9%

Authors' elaboration based on WIOD.

place in recent decades. Although there is a general trend for increasing vertical specialisation as countries has become more integrated into GVC, a sectoral perspective shows that some industrial chains were more affected than others, and this outcome varies significantly according to countries' stages of development. Whereas fragmentation is very important for high-tech industries in developing countries, in advanced economies, it was a process verified specially in low-tech sectors. Moreover, integration into GVC was seen to be more generalised process for some countries, such as in China and Mexico, whilst in others, it is specific in some sectors, such as in the Brazilian mining and high-tech industries, in the Indian high-tech industries and in the Korean low-tech industries.

6.4 Decomposition of the net impact of fragmentation

By analysing only the degree of VS it is not possible to evaluate the importance of the fragmentation process to boost economic growth. On the one hand, an increase of VS impacts directly on the value added embodied in exports by decreasing the domestic content of exports, once the share of foreign value added increases. On the other hand, production fragmentation can boost sectoral exports as countries are integrated into GVC, and hence it can increase the market share of this economy. Thereby, to analyse the impact of these changes in the structure of production and trade it is necessary to take into account the net impact of the increase in VS.

Moreover, such as discussed before, the benefits and costs of losing linkages and industrial commons due to outsourcing depends significantly on the sector this in which process is taking place. Because sectors have different potential to promote growth in the long term, the analysis of whether fragmentation brings benefits or costs for high and sustained economic growth, besides considering the net impact of VS, must consider this impact sectorally.

In order to measure the net impact of the process of integration into GVC from a sectoral perspective, changes in the VS_{ki} are decomposed into the impact of exports growth and the impact of changes in the imported inputs coefficients through a Structural Decomposition Analysis (SDA)[104]. Changes in the VS_{ki} from period t=0 to period t=1 is given by:

$$\Delta VS_{ki} = VS_{ki}^{1} - VS_{ki}^{0} \tag{6.8}$$

where the superscripts stands for the period under consideration.

Based on equation (6.6), and defining $L^{M1} = L^{M0} + \Delta L^{M}$, and $\hat{f^{E1}} = \hat{f^{E0}} + \Delta \hat{f^{E}}$, changes in VS can be expressed through the SDA average approach[105] method as:

$$\Delta VS_{ki} = \frac{1}{2}\iota'(\Delta L^{M})(\hat{f^{E0}} + \hat{f^{E1}})\mu_i + \frac{1}{2}\iota'(L^{M0} + L^{M1})(\Delta \hat{f^{E}})\mu_i \tag{6.9}$$

The first component of equation (6.9) measures the direct and indirect impact of changes in the matrix of imported inputs on the foreign value added embodied in exports in absolute terms, whilst the term on the right side measures the impact of the increase in exports also in absolute terms. Thereby, an increase in the fragmentation of production (given exports) positively affects the term on the left side, and an increase in exports (given the degree of VS) positively affects the term on the right side.

Equation (6.9) measures the direct impact of vertical specialisation and impact of exports growth in imported inputs. However, because this chapter is focused on the impacts on the domestic value added embodied in exports, rather than analysing the growth of imported inputs, the domestic content of exports (DCE) is considered. Analogously to the procedure adopted to estimate it in equation (6.9), following Castillo and de Vries (2014), the impacts of production fragmentation in the DCE can be measured by considering that:

[104] See Miller and Blair (2005) for details about this approach.
[105] According to Dietzenbacher and Los (1998), this approach is a preferable method for SDA.

$$DCE_{ki} = \iota' \hat{f^E} \mu_i - VS_{ki} \tag{6.10}$$

This equation shows that exports growth increases the domestic content of exports, but this impact is reduced due to the direct impact vertical specialisation, or, in other words, due to the increase of imported inputs embodied in exports.

Defining changes in DCE_{ki} as:

$$\Delta DCE_{ki} = DCE_{ki}^1 - DCE_{ki}^0 \tag{6.11}$$

and replacing equations (6.6) and (6.10) in equation (6.11), the growth in the DCE can be written as a function of the matrix of direct and indirect imported inputs and the vector of exports, as follows:

$$\Delta DCE_{ki} = \iota'(I - L^{M1})\hat{f^{E1}}\mu_i - \iota'(I - L^{M0})\hat{f^{E0}}\mu_i \tag{6.12}$$

Proceeding with the average method for the SDA, the growth in the domestic content of exports can be divided into two components: (i) the direct impact of increasing vertical specialisation, which negatively affects the domestic value added embodied in exports, and (ii) the impact of exports growth, which affects value added positively:

$$\Delta DCE_{ki} = \underbrace{\frac{1}{2}\iota'(-\Delta L^M)(\hat{f^{E0}} + \hat{f^{E1}}\mu_i}_{(i)} + \underbrace{\frac{1}{2}\iota'(2I - L^{M0} - L^{M1})(\Delta\hat{f^E})\mu_i}_{(ii)} \tag{6.13}$$

Equation (6.13) divides the changes in the DCE into the direct impact of production fragmentation, presented by the term on the left side, and its indirect impact, on the right side, if one assumes that all increase in exports is due to increasing in VS.

However, due to many factors, countries' exports tend to grow independently of this fragmentation process. Thereby, in order to measure the net impact of this process, it is more appropriate to compare the direct negative impacts of the increase of VS in the domestic value added embodied in exports with the impact of the growth in the market share of the sector under consideration. Essentially, by doing this, it is assumed that the fragmentation of production has two impacts on the value added embodied in exports. Firstly, one negative, which is due to the substitution of domestic content for imported inputs, and, secondly, one positive, which is the impact of the increase in the market share of the sector in world exports.

In order to proceed with this analysis, sector i's export growth is divided into two components: the impact of world exports and the impact of the growth in the world market share:

$$\Delta f_i^E = \Delta Z_i^E \frac{MS_i^{E0} + MS_i^{E1}}{2} + \Delta MS_i^E \frac{Z_i^{E0} + Z_i^{E1}}{2} \tag{6.14}$$

where Z_i^E is sector i's world exports, and MS_i^E is sector i's market share in world exports. The term on the left side measures the impact of the increase in sectoral world exports on countries' export growth and the term on the right measures the impact of countries' growth in the world market share on its export growth.

Replacing equation (6.14) in equations (6.9) and (6.13), we are finally able to measure the net impact of VS on productive chains, as follow:

$$\Delta VS_{ki} = \underbrace{\frac{1}{2}\iota'(\Delta L^M)(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}_{(i)} + \underbrace{\frac{1}{4}\iota'(L^{M0} + L^{M1})\Delta\hat{Z^E}(M\hat{S}^{E0} + M\hat{S}^{E1})\mu_i}_{(ii)} +$$

$$+ \underbrace{\frac{1}{4}\iota'(L^{M0} + L^{M1})\Delta M\hat{S}^E(\hat{Z^{E0}} + \hat{Z^{E1}})\mu_i}_{(iii)} \tag{6.15}$$

and

$$\Delta DCE_{ki} = \underbrace{\frac{1}{2}\iota'(-\Delta L^M)(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}_{(i)} + \underbrace{\frac{1}{4}\iota'(2I - L^{M0} - L^{M1})\Delta\hat{Z^E}(M\hat{S}^{E0} + M\hat{S}^{E1})\mu_i}_{(ii)} +$$

$$+ \underbrace{\frac{1}{4}\iota'(2I - L^{M0} - L^{M1})\Delta M\hat{S}^E(\hat{Z^{E0}} + \hat{Z^{E1}})\mu_i}_{(iii)} \tag{6.16}$$

The first component of equations (6.15) and (6.16), (i), such as discussed before, measures the direct impact of VS in the foreign and domestic value added embodied in sectoral exports. If fragmentation of production is increasing, this value will be positive in (6.15) and negative in (6.16), once imported inputs are increasing to the detriment of domestic content. The second component, (ii), measures the impact of the growth in world exports in the sectoral foreign and domestic value added in exports. This component is considered to be autonomous and independent of the increase in the degree of VS. Finally, the third component, (*iii*), is the impact of the growth in the market share of the sector under consideration, and it measures the positive impact of production fragmentation. The *rationale* behind this assumption is that although fragmentation of production decreases the domestic content of exports because it is replaced by imported inputs, VS increases the competitiveness of the sector in external markets, promoting gains in the market share, which, in turn, increases both the foreign and domestic value added in exports. Thereby, to analyse the net impact of countries' integration in GVC, one should compare the direct negative impact on DCE provided by the first component of equation (6.16) and the indirect positive impact provided by the last component of this equation.

Finally, because these results present the impact of VS in absolute terms, it is inadequate to compare countries and sectors. In order to make these impacts comparable, it is necessary to consider these impacts relatively to exports. Defining $\Delta\%VS_{ki}$ and $\Delta\%DCE_{ki}$ as the change in VS and DCE as a share of sectoral exports, the impact of fragmentation on these variables can be written as:

$$\Delta\%VS_{ki} = \underbrace{\frac{\iota'(\Delta L^{M})(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}{\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(i)} + \underbrace{\frac{\iota'(L^{M0} + L^{M1})\Delta\hat{Z^{E}}(\hat{MS^{E0}} + \hat{MS^{E1}})\mu_i}{2\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(ii)} + \\ + \underbrace{\frac{\iota'(L^{M0} + L^{M1})\Delta\hat{MS^{E}}(\hat{Z^{E0}} + \hat{Z^{E1}})\mu_i}{2\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(iii)} \tag{6.17}$$

and

$$\Delta DCE_{ki} = \underbrace{\frac{\iota'(-\Delta L^{M})(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}{\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(i)} + \underbrace{\frac{\iota'(2I - L^{M0} - L^{M1})\Delta\hat{Z^{E}}(\hat{MS^{E0}} + \hat{MS^{E1}})\mu_i}{2\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(ii)} + \\ + \underbrace{\frac{\iota'(2I - L^{M0} - L^{M1})\Delta\hat{MS^{E}}(\hat{Z^{E0}} + \hat{Z^{E1}})\mu_i}{2\iota'(\hat{f^{E0}} + \hat{f^{E1}})\mu_i}}_{(iii)} \tag{6.18}$$

6.5 Empirical results: the net impacts of fragmentation

Using the same database method to deflate data and aggregation used in Section 6.2, the impact of fragmentation of production is analysed for some developing and developed economies between 1995 and 2008 through equations (6.17) and (6.18).

6.5.1 Results for the overall economy

Table 6.4 presents the results for the overall economy. It shows that the net impacts of integration in GVC varies significantly across countries. The first three columns present the structural decomposition of VS and, the last three, the structural decomposition of DCE. The first and forth columns present the impact of changes in imported inputs coefficients, the second and the fifth, the impact of exports growth in the world market share, and, the third and sixth, the impact of world exports growth.

Table 6.4: Structural Decomposition of VS and DCE, 1995-2008 (1995 USD prices)

	Vertical Specialisation			Domestic Content of Exports		
	Imp.	MS	WLD	Imp.	MS	WLD
Brazil	2.7%	-0.4%	2.9%	-2.7%	-1.0%	17.3%
China	5.0%	6.7%	5.2%	-5.0%	17.1%	12.7%
India	3.1%	2.7%	3.1%	-3.1%	11.5%	14.7%
Mexico	1.9%	0.4%	9.2%	-1.9%	-4.1%	16.0%
South Korea	0.0%	2.6%	5.7%	0.0%	8.1%	16.3%
Germany	1.9%	-0.4%	4.8%	-1.9%	-1.0%	17.5%
Japan	1.3%	-0.6%	2.3%	-1.3%	-4.9%	22.9%
United States	0.9%	-1.3%	3.2%	-0.9%	-7.7%	22.1%
Simple average	2.1%	1.2%	4.6%	-2.1%	2.2%	17.4%

Imp.: Impact of changes in imported inputs coefficients; MS: Impact of exports growth in the world market share; WLD: Impact of world exports growth.
Authors' elaboration based on WIOD.

In every analysed country, the direct impact of changes in imported inputs is positive for VS and negative for DCE. This result could be expected once fragmentation of production has increased in all these economies, such as presented in Section 6.2. In China, where the increase in fragmentation was the greatest, the increase of imported inputs has increased the foreign value added of exports as a share of exports by 5.0%, while it has decreased the domestic value added of exports by the same amount. In contrast to China, in South Korea and the US, the impact of this fragmentation process was less significant: in the US, fragmentation has increased imported inputs embodied in exports by 0.9%, whilst in South Korea, where the degree of VS virtually remained unchanged, the impact of fragmentation was neutral.

However, focusing only on the direct impact of fragmentation (first and forth columns) can lead to a false recognition that fragmentation is certainly a process that increases imported inputs and decreases the domestic content of exports. If one considers that growth in the world market share is, to some extent, an indirect effect of this fragmentation process, different results can be observed. In China and India, for example, the impact of the growth of market share on the DCE has compensated for the negative impact of the increase in imported inputs due to production fragmentation. In China, the growth in the market share increased the domestic content of exports by 17.1%, and thus the net impact of fragmentation on the DCE was 12.1%. In India, although fragmentation has negatively affected the DCE by 3.1%, this impact was compensated for a growth in the world market share, which has increased the value added embodied in Indian exports by 11.5%.

Among the more advanced countries, South Korea was the only economy where the net impact was positive. In South Korea, because the degree of VS has not changed significantly, fragmentation has a neutral direct impact. However, the growth in market share has positively affected the value added embodied in exports, increasing it by 8.1%. In the other developed countries, as well as in Mexico and Brazil, the increase in the market share has not compensated for the negative impact of the growth in imported inputs. In these countries, the market share in world exports has reduced and thus the net benefits of increasing fragmentation was negative. In Mexico, Japan and the US, the decrease of market share has significantly affected the domestic value added embodied in exports, decreasing it by more than 4.0%, whereas the negative impact in Brazil and Germany was less significant (1.0% in both cases).

6.5.2 Results for the sectoral chains

The analysis for the overall economy is important once it shows to what extent the fragmentation process has been affecting their value added embodied in exports, and hence countries' GDP. However, as stressed before, the benefits and costs of fragmentation varies significantly among sectors, once they have different capabilities to promote high and sustained growth rates. Thereby, the analysis of the impact of production fragmentation on countries' value added embodied in exports must consider a sectoral approach.

Table 6.5 presents the impact of the increase in imported inputs and the impact of the growth in world market share for developing countries sectorally. The net impact of the fragmentation process on the domestic content of exports (the sum of the direct impact of decreasing value added due to the substitution for imported inputs and the impact of the increase in the world market share) varies significantly among countries, such as stressed before, but it varies mainly across sectors in the same country.

Table 6.5: Decomposition of DCE, 1995-2008 (1995 USD prices), developing countries

	Brazil		China		India		Mexico	
	Imp.	MS	Imp.	MS	Imp.	MS	Imp.	MS
Total	-2.7%	-1.0%	-5.0%	17.1%	-3.1%	11.5%	-1.9%	-4.1%
Primary Sectors	-2.5%	6.2%	-6.2%	-17.5%	-0.8%	3.8%	-1.3%	-17.1%
Agriculture	-1.6%	11.1%	-2.8%	-12.9%	-0.5%	3.9%	-1.7%	-9.8%
Mining	-3.6%	-0.4%	-11.5%	-24.5%	-1.5%	3.5%	-1.1%	-19.1%
Manufacturing	-3.2%	-3.0%	-5.0%	17.1%	-3.9%	10.1%	-2.1%	0.3%
Low Tech	-2.5%	-3.8%	-2.6%	15.8%	-4.8%	8.0%	-2.6%	-4.4%
Med/High Tech	-4.3%	-1.7%	-6.3%	17.8%	-2.0%	14.7%	-1.9%	1.6%
Chemicals	-5.3%	-14.3%	-10.0%	17.7%	-2.8%	7.9%	-2.3%	-13.7%
Machinery	-2.8%	-1.7%	-4.0%	24.2%	-1.5%	14.6%	-6.3%	2.6%
Electrical	-6.0%	-10.2%	-6.9%	15.8%	-1.7%	16.3%	-1.7%	1.6%
Transport	-3.9%	6.2%	-2.9%	24.7%	-1.8%	21.0%	-1.8%	3.3%
Services	-0.8%	-0.1%	-4.9%	20.2%	-0.9%	19.0%	-1.1%	-22.1%

Imp.: Impact of changes in imported inputs coefficients; MS: Impact of exports growth in the world market share.
Authors' elaboration based on WIOD.

Although the direct impact negative of increasing vertical specialisation on the domestic value added embodied in exports is generalised for all countries and all sectors, it was more significant for some sectors than for others. In China, for example, the negative impact on the high-tech industries was significantly greater than it was in the low-tech industries. However, the growth in the market share in the most technologically advanced sectors has compensated more significantly for this negative impact, with special regards to machinery and transport. In high-tech manufacturing sectors, although fragmentation has reduced the DCE as a share of exports by 6.3%, the growth in the market has contributed for an increase of 17.8%, providing a net impact of 11.5%. Chinese primary sectors, on the other hand, have become more fragmented, but it was not compensated for by an increase in the market share. The increase in imported inputs has negatively impacted the Chinese domestic content of primary exports by 4.2%. However, Chinese market share in world exports has decreased, and hence the net impact of fragmentation was negative for primary sectors.

Value added embodied in Brazilian manufacturing exports was negatively impacted by the increase in fragmentation, but, in contrast to China, it was not compensated for by the increase in the market share. In primary sectors, on the other hand, although the direct impact of fragmentation has reduced the DCE, an increase in the market share, in which agriculture plays a prominent role, has a significant impact, and hence the net impact was positive. The growth of the degree of VS in primary sectors, which increased from 5.7% to 15.9% between 1995 and 2008 (as presented in Section 6.3), negatively impacted the domestic value added embodied in exports by 2.5%. However, Brazil has increased its market share in world exports in primary sectors, and, once the DCE increased by 6.2%, the net impact was positive. Moreover, although the net impact of VS in Brazilian high-tech industries was negative, not all high-tech sectors follow the same pattern. In transport, fragmentation of production has directly impacted by reducing the DCE by 3.9%. However, the growth in the market share of world exports has compensated for this negative impact, increasing the domestic value added by 6.2%, and hence guaranteeing a positive net impact in this industry.

The results for India are very similar to those found for China. In manufacturing sectors, the loss of DCE due to the direct impact of fragmentation was compensated for by the positive impacts of growth in the market share in both high-tech and low-tech industries. The main difference between China and India is that the net impact of fragmentation on Indian value added embodied in exports was positive also in primary sectors, whilst it was negative in China. Fragmentation has reduced Indian domestic content of primary sectors exports by 0.8%, but the increase in world market share has affected it positively, increasing the DCE by 3.8%.

Finally, in the case of Mexico fragmentation has affected negatively both low-tech and high-tech manufacturing, as well as primary sectors. Although the market share of high-tech exports has increased, it was not enough to compensate for the direct negative impact of production fragmentation on the domestic value added embodied in exports. Only in transport has the increase of market share compensated for the negative impacts of fragmentation. The difference between the negative impact in primary sectors, low-tech industries and high-tech industries, however, shows that although negatively affected by this process, primary sectors were the most damaged sectors, whereas high-tech industries relatively benefited from this process.

The analysis of the results for developed countries, presented in Table 6.6, reinforces the importance of analysing the impact of countries' integration in GVC sectorally, once the net impact of fragmentation varies significantly among sectors. Even though the analysis of the aggregate economy showed that South Korea was the only developed country that benefited from this process of fragmentation, the sectoral analysis shows that low-tech manufacturing industries in Germany has increased the market share, as well as services and agriculture. Moreover, in the case of agriculture and services, the growth in world market share was enough to compensate for the negative impacts of fragmentation.

Table 6.6: Decomposition of DCE, 1995-2008 (1995 USD prices), developed countries

	South Korea		Germany		Japan		United States	
	Imp.	MS	Imp.	MS	Imp.	MS	Imp.	MS
Total	0.0%	8.1%	-1.9%	-1.0%	-1.3%	-4.9%	-0.9%	-7.7%
Primary Sectors	-0.7%	-35.7%	-1.1%	-4.3%	-4.0%	-5.6%	-2.3%	-15.9%
Agriculture	-0.7%	-29.8%	-1.0%	6.2%	-0.5%	9.2%	-1.4%	-7.3%
Mining	-1.9%	..*	-1.4%	-42.7%	-5.5%	-12.2%	-5.6%	-47.1%
Manufacturing	0.4%	9.5%	-2.1%	-1.7%	-1.4%	-4.2%	-1.0%	-7.3%
Low Tech	-6.0%	-7.1%	-2.5%	0.7%	-3.9%	-6.2%	-3.1%	-8.9%
Med/High Tech	1.6%	12.5%	-1.9%	-2.8%	-0.9%	-3.8%	-0.2%	-6.8%
Chemicals	-3.8%	4.7%	-1.7%	-2.2%	-3.1%	-8.9%	-3.5%	-9.8%
Machinery	-0.6%	12.3%	-2.6%	-3.1%	-0.9%	-3.3%	-2.0%	-8.8%
Electrical	3.3%	13.4%	-0.9%	-6.1%	-0.1%	-6.1%	1.8%	-6.1%
Transport	-2.1%	12.3%	-2.6%	-0.2%	-1.4%	0.7%	-1.5%	-5.4%
Services	-3.1%	-3.4%	-0.7%	4.7%	-0.7%	-9.5%	-0.7%	-7.6%

(*) Korean mining exports were negative in 1995. Thus, the impact cannot be computed.

Imp.: Impact of changes in imported inputs coefficients; MS: Impact of exports growth in the world market share.

Authors' elaboration based on WIOD.

In the US and Japan, the same result found for the aggregate was found in the sectoral chains. In all sectors, the negative impact of fragmentation has not been compensated for by the increase of market share. The intensity of the negative impact, however, varies among sectors. The net impact was higher in primary sectors than manufacturing in both countries, and, inside manufacturing, low-tech industries were affected the most. In high-tech industries, the negative impact of fragmentation was not as significant as in industries with low technologic intensity, and the impact of the loss of market share was also less relevant. The Transport industry in Japan was an exception in this trend. Despite not being sufficiently high to compensate for the direct negative impact of fragmentation, this industry has gained market share and it has impacted positively by 0.7% in the domestic value added embodied in Japanese exports.

In South Korea, although results for the aggregate economy are positive in net terms, in some sectors the impact was significantly negative, whilst in other sectors it was very positive. Primary sectors were the most negatively affected: fragmentation has reduced the domestic content of primary sectors exports by 0.7%, and the loss of market share has reduced it by 35.7%. The net impact on low-tech industries was negative as well, with the outsourcing process decreasing the DCE by 6.8% and the loss of market share by 5.7%. The Korean high-tech industries, on the other hand, have been positively affected in net terms. Although the direct impact of fragmentation has decreased domestic value added embodied in chemicals, machinery and transport exports by 3.8%, 0.6% and 2.1%, respectively, the gain in world market share has increased the DCE of these industries by 4.7%, 12.3% and 12.3%, respectively. In electrical, both the direct and indirect impacts were positive because the degree of VS has decreased and the market share has increased. Thereby, looking for productive chains rather than for the aggregate can bring us important conclusions about this process of fragmentation, showing that this impact is far from being homogeneous among sectors.

6.6 Concluding remarks

In recent decades, countries' productive chains have become more integrated internationally and, therefore, more fragmented domestically. From the perspective of firms, this process is usually seen as positive, once fragmentation has increased their competitiveness by reducing costs and increasing the possibility for an interchange of knowledge and technologies, especially for firms in developing countries. Nevertheless, the benefits for countries is much more controversial: although these benefits for firms can be extended for countries, many authors, such as Pisano and Shih (2009) and Berger (2013), have argued that the critical strengths and capabilities that help the development of new products and process have been lost due to this outsourcing process. Moreover, such as discussed in the latter chapters, especially regarding high-tech and capital good products, technological change is induced by production, and hence outsourcing may damage countries' potential to innovate if it is not compensated for an increase in competitiveness. Thereby, a sectoral analysis of this fragmentation processes is necessary to understand its consequences for countries' growth in the long term.

This chapter showed that, despite being a generalised process, vertical specialisation of production varies significantly among sectors and countries. In some countries, such as China, Mexico and India, fragmentation was more generalised, affecting all sectors and industries. In contrast to these countries, in South Korea, Japan and in the US, this process was much more intense in low-tech manufacturing and primary sectors than in high-tech industries, showing that the increase in the foreign value added as a share of exports was not homogeneous among countries and sectors.

The analysis of the impact of fragmentation, however, went further than the direct impact of replacing domestic for foreign value added in exports. Once it is expected that countries that have engaged in integration in GVC might benefit from increasing competitiveness, and hence from gains in the world market share, the positive impact of fragmentation on the DCE was compared to the negative impact. By analysing the net impact of this process, results are very different across countries. In China, India and South Korea, the impact of the increase in the world market share in the value added embodied in exports has compensated for the direct negative impact of fragmentation. However, in the other countries, with especial regards to the US, Japan and Mexico, the growth in the market share was unable to compensate for the negative impact of vertical specialisation on the DCE.

Nevertheless, a sectoral analysis of this process shows that production fragmentation has a heterogeneous impact on the domestic value added in exports among countries. In China and South Korea, for example, the most benefited industries were those classified as high-tech industries (especially Machinery and Transport Equipment), whilst value added in primary sectors exports was negatively affected by outsourcing. In Mexico, for all industries but Electrical and Transport Equipment, the growth in the market share was unable to compensate for the negative impact of fragmentation, as well as in Brazil for all sectors except for Agriculture and Transport Equipment. The only country that has benefited from this process in all sectors was India, although in high-tech industries the benefit was significantly lower than it was in China.

Considering the findings of the latter chapters, which has showed that specialisation in high-tech and capital goods industries is an important source of cumulative causation, these results shows that some countries, such as Japan, the U.S. and Mexico, are not benefiting from this process once the DCE is decreasing in every sector. Moreover, the sectoral analysis shows that although Brazil has engaged in a process of integration into GVC, it is not taking the benefits of this. The sectors where the positive impact of an increase of the market share has compensated for the direct negative impacts of fragmentation in Brazilian DCE are those that do not have potential to guarantee high growth rates in the long term. On the other hand, Chinese, Indian and South Korean high-tech industries were the most benefited industries from this fragmentation process, and, once these industries have the highest potential to promote high and sustained growth rates, these countries are benefiting the most from this process of integration into GVC.

Conclusion

Based on the Kaldorian approach, which stresses the importance of the interaction between demand and supply to explain why countries' growth rates diverge in the long run, this thesis expounds theoretical and empirical evidence that the sectoral structure of production and international trade is a crucial aspect to understanding countries' growth patterns. In the supply-side, once dynamic increasing returns to scale diverge among sectors, productivity growth depends on the sectoral specialisation of production. Nevertheless, because growth is ultimately determined by the growth of demand, with special regard to the dynamics of international trade, countries' long-term growth rates diverge due to the sectoral composition of their exports and imports. In this work, a reconciliation of these two statements is presented to explain how a cumulative causation process of increasing growth rates depends on the sectoral structure of production and trade.

The first chapter provided the theoretical basis of the approach adopted. It argued that although Kaldor stressed the importance of sectoral dynamics to explain cumulative causation in open economies, Kaldorian models did not incorporate it completely, and hence they are unable to provide a systematisation of the importance of sectoral specialisation. Some models show how cumulative causation takes place considering balance-of-payments constraints, but not in multisectoral framework. Other Kaldorian models show how cumulative causation take place in a multisectoral framework through the interaction between scale economies and income elasticities, but they ignore balance-of-payments constraints and their importance as ultimately determinant of countries' growth in the long run. Finally, a third group considers balance-of-payments constraints in a multisectoral framework, but cumulative causation does not arise from sectoral specialisation once technological progress is not endogenous to output growth. In this vein, this chapter advocated for the need for a dynamic model that shows how a cumulative causation takes place in a multisectoral framework for an open economy – which is balance-of-payments constrained in the long term – in order to identify what sectors are capable of promoting the highest growth rates in the long run.

Chapter 2 expands the BPCG models to a multisectoral and multilateral framework in order to evaluate whether the high growth rates experienced by natural-resource exporters' in the 2000s were sustainable in the long term. Due to developing countries' growth acceleration in the 1990s and 2000s, the structure of world demand has changed and the demand for natural-resource-based products has increased relatively faster. Consequently, countries that export predominantly these products, such as South American economies, have experienced an increase in their BPCG rate. Nevertheless, this chapter also shows that capital goods and high-tech manufacturing products present the highest income elasticities of demand for exports and imports, and thus countries must increase the share of exports of these products (and reduce the share of imports) to increase their weighted income elasticity ratio and, consequently, their long-term growth rates.

The following chapter estimates the degree of dynamic increasing returns to scale of individual industries according to countries' income per capita to understand to what extent productivity is induced by output growth. Because the benefits provided by increasing in production varies among industries according to countries' stage of development due to many factors, such as the supply of skilled labour and the existence of a complex system of innovation, it was expected that the degree of increasing returns was not homogenous among countries. Indeed, the results show that the production of consumption goods and low-tech manufacturing, such as Textiles, present a relatively high degree of increasing returns for low-income countries, but constant returns to scale for high-income countries. On the other hand, production in capital goods and high-tech industries present relatively low degree of increasing returns for low-income countries, but it rises as countries' income per capita increases. Thereby, for middle- and high-income countries, productivity growth depends on the specialisation of production in the most technologically advanced sectors.

Chapter 4 is dedicated to developing a sectoral model that combines the explanation for productivity growth, given by dynamic increasing returns to scale, and the divergence of demand growth among countries, given by the BPCG approach. In this model, despite being the ultimately determinant of countries' growth, elasticities are considered partially endogenous to output growth. Because sectoral elasticities reflects non-price competitiveness and this competitiveness, in turn, depends on technological progress, a faster growth rate may induce innovations and increases non-price competitiveness. Consequently, countries' long-term growth rates are induced by output growth, which, in turn, depends on countries' competitiveness in external markets. Based on this, this chapter shows that a process of cumulative causation might take place if countries stimulates those sectors with the highest income elasticities of demand and the highest dynamic increasing returns to scale. Based on the former chapters' results, it shows that, for middle- and high-income countries, specialisation in capital goods and high-tech manufacturing is important to trigger a cumulative causation process of increasing growth rates, whereas specialisation in consumption goods, natural-resource-based products and low-tech manufacturing, on the other hand, might produce a vicious cycle of stagnation.

In Chapter 5, the SDA method is extended to evaluate the impact of substitution between domestic and imported inputs in the overall economy on the sectoral output growth. Based on this approach, it is possible to investigate the sources of countries' growth from a sectoral perspective, as well as to compare the negative impact of this substitution with the positive impact of exports growth that this substitution might have promoted. Although all the analysed countries experienced substitution of imported inputs for domestic suppliers, this process had positive impacts in the vast majority of sectors in the analysed countries. However, the comparison between Brazil, China and South Korea shows that developing economies have been affected differently in sectoral terms. The net impact was positive in Brazil for mining and agriculture, but it was negative for high-tech industries. In China and Korea, high-tech industries benefited the most from this process, and only the agriculture and mining have been negatively affected. Considering the findings of the previous chapters, it is possible to infer that China and Korea has been taking advantage of this process, whilst the impact of substitution of imported inputs on the Brazilian sectoral output has contributed negatively for its long-term growth rates.

Finally, in Chapter 6, the impact of countries' integration into GVC on their productive chains is evaluated through the structural decomposition of the domestic content of exports. The results shows that although vertical specialisation of production is a generalised process, the degree of fragmentation varies significantly among sectors and countries, as well as its net impact on the value added embodied in exports. In China, India and South Korea, the impact of growing market share has compensated for the negative impact of fragmentation, whilst in the other analysed countries, the negative impact of vertical specialisation on the domestic content of exports was not compensated by competitiveness gains. The sectoral analysis shows that the most benefited sectors in China and South Korea were those classified as high-tech industries, whilst fragmentation has impacted negatively on the value added in primary sectors exports. In Mexico, all sectors except for Electrical and Transport Equipment were negatively impacted, as well as all sectors except for Agriculture and Transport

Equipment in Brazil. Based on the findings of the last chapters, these results show that despite the increasing integration into GVC, Mexico and the more advanced countries have been negatively affected by this process once they have experienced a loss of the value added embodied in exports in almost every sector. Moreover, the results shows that Brazil is not taking the benefits of this, once high-tech industries have been negatively impacted, while those sectors that have less potential to guarantee high growth rates in the long run, such as agriculture, were benefited from this integration. In China, India and South Korea, on the other hand, high-tech industries, which are the sectors with the highest capability to promote high growth rates in the long run, were the most benefited industries from the process of vertical specialisation.

Despite its clear importance in the historical analysis focused on explaining countries' growth divergence and catching-up processes, sectoral dynamics have received little attention in economic growth theories. The vast majority of approaches either completely ignore this aspect or consider it only implicitly. Not by chance, policy orientations of the most important development institutions are usually sector-neutral. They are based on the belief that industrial policies, with special regards to "selective" or "vertical" industrial policies, should be avoided because they create market distortions in favour of non-competitive sectors. They advocate that governments should help all business activities homogenously, independently of what they produce, and, if any assistance is given to industries, they should be through "horizontal" policies, such as investing in infrastructure supply and skilled workforce or subsided credit for small and medium firms, once they have limited access to financial markets due to market failures. As the Nobel laureate Gary Backer once said, "the best industrial policy is none at all".

In contrast to this view, this work has shown that growth and stagnation in developing countries are intrinsically related to their sectoral composition of production and trade. Thus, stimulating specific sectors may be important to promote sustained high growth rates in the long-term. Because goods produced by sectors are different (and consumers value it), income elasticities of demand for imports and exports varies among sectors. Consequently, what you export (and import) matters. Furthermore, because the process of production is intrinsically different among sectors, sectoral specialisation determines countries' potential to promote technological progress and productivity growth. Thereby, there is no sense of neglecting "selective" industrial policies only because it promotes market distortions, once these distortions are important to guarantee sectors growing at different rates. Sector-specific industrial policies are crucial to promote structural changes in favour of those sectors able to promote positive cycles of cumulative causation.

This work has focused on middle-income countries, especially regarding the difference between Latin American and East Asian countries' patterns of growth. Different from low-income countries, which has (quasi)unlimited labour supply and hence can grow by transferring workers from less productive to more productive sectors, middle-income countries must promote productivity growth within sectors to reach faster growth rates. However, they cannot compete in international markets with low-income countries in low-tech sectors, where wages tend to be higher in middle-income countries, and they find it difficult to compete in high-tech industries with high-income countries, once they have been producing these goods for decades and they already have a complex ecosystem of production and innovation. The "middle-income trap" relies on the fact that middle-income countries must move from low-tech sectors to high-tech sectors to avoid a vicious cycle of decreasing growth rates, but letting the market work by itself is not enough. Therefore, "selective" industrial policies focused on promoting more technological advanced industries is crucial to re-orientate these countries towards a virtuous cycle of increasing growth rates.

Before discussing direct selective industrial policies, however, it is necessary to consider the importance of the management of macroeconomic variables for sectoral dynamics. Even though one may argue that macroeconomic policies are sector-neutral, the management of macroeconomic variables, such as exchange and interest rates, affects differently sectors according to their structure of production and trade. Nowadays, macroeconomic policies in the vast majority of developing countries are mainly focused on price stability under the argument that it is a necessary condition for investment. However, in countries that adopt inflation targeting monetary policies , for example, the costs of inflation control is sometimes paid by currency overvaluation, because increasing interest rates promote capital inflows. Consequently, more outward oriented sectors are negatively affected, whilst those focused on domestic markets tend to be positively affected. Exchange rates management is an important issue especially for natural-resource exporters due to the "Dutch disease". Because export of natural-resource based products might stimulate currency valuation in the absence of capital controls, high-tech manufacturing exports might be negatively affected. Hence, the degree of financial openness and the management of exchange rates are not sector-neutral. Moreover, not only the level, but also the degree of volatility of exchange rates is an important determinant of countries' sectoral dynamics. Macroeconomic policies oriented to pursue stable exchange rates are crucial to promote countries' integration into GVC. Because in fragmented production processes imported inputs are relevant part of costs, the adoption of measures to reducing currency volatility reduce the uncertainty of these investments. Therefore, due to the above-mentioned factors, one cannot ignore the effects macroeconomic policies on sectoral dynamics. Despite not being a selective industrial policy *per se*, the management of macroeconomic variables can be used to promote some sectors to the detriment of others. Moreover, if not well managed, macroeconomic policies can turn out selective industrial policies ineffective.

A good design of industrial policies is important to increase their probability of success. Although industrial policies are sometimes associated with selective import tariffs or subsides for exports, the core of possibilities is much more embracing, and they must be thought according to sectoral needs. Once countries define the sectors that will be the target of these policies, one should assess the stage of development of these sectors in terms of their international competitiveness, technological gap and integration into global networks to decide what kind of policy will be adopted. In middle-income countries, the stage of development varies significantly among segments inside an industry, and one of the most important features of selective industrial policies is that they can be designed for very specific cases according to their needs.

Target industries in early stages of technological development demand policies focused on technological absorption from abroad to create local firms with world-class productive capabilities. Foreign Direct Investment (FDI) plays an important role in these cases because it is very difficult to reach the technological level of competitive firms without their cooperation. Thereby, governments should create favourable conditions to attract FDI offering custom-designed incentives. Temporary imports tariffs and quantitative restrictions were methods employed by the vast majority of developed countries to develop new or infant industries in the past. Although these methods cannot be discarded, they must be combined with technological incentives, such as networks of science parks and incubators. Nevertheless, direct technological transfer needs coordination to ensure that imported technology is not obsolete and outdated, and hence governments must have explicit conditions in these transfers to ensure that technological capabilities will be created domestically. The process of creation of competitive local producers takes time and needs the cooperation of current internationally competitive firms, but it will only succeed with strong government coordination through special requirements for joint ventures and direct investments of Trans-National Companies (TNC).

In the case of already established firms, selective policies focused on increasing competitiveness in target sectors are different from those focused on creating competitive industries. Industrial policies need to promote continuous investment in productivity capacity and R&D to guarantee firm's technological update. Instruments of industrial policy to promote competitiveness goes beyond those traditional measures. Coordination of investment between different industries, for example, promotes complementary investments. Finance systems focused on industrial development with subsided interest rates for target sectors makes long-term investments more attractive. Long-term strategies and investments to develop skilled workers for specific activities ensure that growth of these activities will not be constrained by skilled labour shortage. Public investment in basic science and industrial research, subsides for R&D and special conditions for specific innovation activities ensure that companies will have access to cutting-edge technologies and that they will able to take part of most advanced technology developments. The coordination of all these policies is necessary to ensure that local industries of target sectors will reach the technological frontier and will be able to keep as world-class competitors.

Selective industrial policies also need to consider the importance of insertion in global value chains to promote sectoral growth. The benefits of countries' engagement into these global networks depends on the capacity of countries to promote sectors with the highest income elasticities if demand and the highest potential to induce technological progress. Thereby, subsides for exports, reduced utility bills, preferential tax breaks, as well as the provision of adequate infrastructure focused on specific activities are important to integrate globally sectors considered essential to ensure high and sustained growth rates. Moreover, it is also important to promote a national team of strategic companies through consolidation of small uncompetitive firms. Besides creating conditions for these companies to compete internationally, they can be pillar industries for clusters of small and medium firms with high technological capabilities. The examples of South Korea and China, which have been benefiting from the production fragmentation process, show that increasing the world market share through vertical specialisation demands the consolidation of large national groups in target sectors.

All these industrial policies, however, depend on strong institutional cooperation. The consolidation of a national plan for long-term development based on target sectors needs to be validated by the whole society. Industrials of non-target industries have to agree with the transformation that will take place in country's sectoral structure of production and trade because they have to move to these target sectors. Financial markets need to be structured to provide long-term capital to these sectors. Workers must be clearly informed that structural changes are costly and it might have some drawbacks in the early stages. Finally, governments (especially those of democratic countries) need to have a long-term perspective, that it may take more than four or five years (which is usually the government mandates) before the benefits of these structural changes start being reaped. Thereby, intermediate institutions that promote communication and cooperation, such as labour, industrial and bank affiliations, public and semi-public institutions and local governments need to participate in the discussion of which are those sectors that promote countries' long-term development, and hence which of these will be the target of industrial policies.

In this vein, based on the Kaldorian approach, this work showed which sectors are capable of sustaining high economic growth rates in the long term. Essentially, it argues that once high-tech and capital good sectors present the highest dynamic scale economies and the highest income elasticities of demand for imports and exports, promoting these sectors is important to trigger a cumulative process of increasing growth rates. Those countries that have been promoting these sectors are the ones more able to reach sustainable high growth rates in the long term. Thereby, Latin American countries should promote these sectors through custom-designed industrial policies to avoid a vicious cycle of decreasing growth rates and stagnation.

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Appendices

Appendix A

Classification and deflators, Chapter 2

Table A.1: Correspondence table to aggregate and deflate data according to categories of demand

BEC (based on SITC, Rev.1)	Group	Source/Price index*
11 – Food and beverages, primary	NR	UN/Agric. raw materials
12 – Food and beverages, processed	NR	UN/All food
2 – Industrial Suppliers n.e.s.	NR	UN/Minerals, ores and metals
3 – Fuels and lubricants	NR	UN/Minerals, ores and metals
4 – Capital goods	KG	PWT/Capital formation
51 – Transport equip., passenger motor cars	CG	PWT/Household Consumption
52 – Transport equip., others	KG	PWT/Capital formation
53 – Transport equip., parts and accessories	KG	PWT/Capital formation
6 – Consumer goods, n.e.s.	CG	PWT/Household Consumption
7 – Goods, n.e.s.	CG	PWT/Household Consumption

(*) UN: UNCTAD Free Market Commodities Price Index; PWT: Penn World Table – imports are deflated by each country's price indices, and exports are deflated by the US price indices.

Table A.2: Correspondence table to aggregate and deflate data according to technological intensity

ISIC, Rev. 2 (based on SITC, Rev.1)	Group	Source/Price index*
1 - Agriculture, Hunting, Forestry and Fishing	PR	UN/Agricultural raw materials
2 - Mining and Quarrying	PR	UN/Minerals, ores and metals
31 - Food, Beverages and Tobacco	LT	PWT/Household Consumption
32 - Textile, Wearing Apparel and Leather	LT	PWT/Household Consumption
33 – Wood Products, Incl. Furniture	LT	PWT/Household Consumption
34 - Paper Products, Printing and Publishing	LT	PWT/Household Consumption
351 - Industrial chemicals	HT	PWT/Capital formation
352 - Other chemical products	HT	PWT/Capital formation
353 - Petroleum refineries	LT	PWT/Household Consumption
354 - Miscellaneous products of petr. and coal	LT	PWT/Household Consumption
355 - Rubber products	LT	PWT/Household Consumption
356 - Plastic products not elsewhere classified	LT	PWT/Household Consumption
36 - Non-Metallic Mineral Products	LT	PWT/Household Consumption
37 - Basic Metal Industries	LT	PWT/Household Consumption
381 - Fabricated metal products, except M&E	LT	PWT/Household Consumption
382 - Machinery except electrical	HT	PWT/Capital formation
383 - Electrical machinery apparatus	HT	PWT/Capital formation
384 - Transport equipment	HT	PWT/Capital formation
385 – Optical, profess. and scientific equip.	HT	PWT/Capital formation
39 - Other Manufacturing Industries	LT	PWT/Household Consumption

(*) UN: UNCTAD Free Market Commodities Price Index; PWT: Penn World Table – imports are deflated by each country's price indices, and exports are deflated by the US price indices.

Appendix B

Estimation method and results for income elasticities, Chapter 2

Table B.1: Results and methods to estimate income elasticities for Brazil (Subsection 2.4.2)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	2.345***	3.506***	3.410***						
	(0.336)	(0.656)	(0.553)						
$\ln(Y^{HIC})$				1.360***	4.773***	3.533***			
				(0.124)	(0.247)	(0.283)			
$\ln(Y^{LIC})$							2.194***	2.704***	2.672***
							(0.117)	(0.184)	(0.380)
$\ln(RER)$	1.577	-1.492	1.464	0.187	-0.298	-0.096	-0.432	1.639***	0.675
	(1.029)	(1.882)	(1.700)	(0.243)	(0.801)	(0.917)	(0.346)	(0.543)	(1.123)
Method	rc1	rc3	rc1	c2	OLS	OLS	rc1	rc1	rc1

Methods – Letters: (rc) intercept (no trend) in CE, no intercept or trend in VAR; (c) intercept in CE and VAR, no trends in CE and VAR; and (rt) intercept in CE and VAR, linear trend in CE, no trend in VAR. Numbers correspond to lag structure. OLS1d: OLS in first differences for variables non co-integrated. OLS: OLS for stationary variables.

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.2: Results and methods to estimate income elasticities for All Sample by categories of demand (Subsection 2.4.3)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.403***	1.587***	1.770***						
	(0.077)	(0.140)	(0.123)						
$\ln(Y^{HIC})$				1.773***	3.316***	4.810***			
				(0.195)	(0.353)	(0.500)			
$\ln(Y^{LIC})$							2.632***	2.917***	3.927***
							(0.178)	(0.254)	(0.338)
$\ln(RER)$	0.007	-0.979***	-0.733***	0.376**	0.087	0.420	0.745***	-0.038	1.201***
	(0.097)	(0.176)	(0.154)	(0.147)	(0.266)	(0.378)	(0.183)	(0.261)	(0.348)
Method	G:psar1cd	D:l1f0	D:l1f0	D:l1f2	G:psar1cd	D:l1f0	D:l1f3	D:l1f0	D:l1f3

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.3: Results and methods to estimate income elasticities for South America by categories of demand (Subsection 2.4.3)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.622***	2.005***	1.520***						
	(0.133)	(0.291)	(0.22)						
$\ln(Y^{HIC})$				1.447***	3.185***	3.385***			
				(0.187)	(0.463)	(0.307)			
$\ln(Y^{LIC})$							2.061***	2.889***	2.589***
							(0.168)	(0.361)	(0.283)
$\ln(RER)$	0.171	-1.021***	-0.930***	0.192	0.481	0.566***	0.154	0.249	0.537**
	(0.112)	(0.245)	(0.186)	(0.126)	(0.312)	(0.207)	(0.154)	(0.331)	(0.26)
Method	G:psar1cd	D:l1f0	D:l1f0	D:l1f0	G:psar1cd	D:l1f0	D:l1f1	D:l1f2	D:l1f2

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.4: Results and methods to estimate income elasticities for South and East Asia by categories of demand (Subsection 2.4.3)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.353***	1.460***	1.811***						
	(0.092)	(0.142)	(0.145)						
$\ln(Y^{HIC})$				2.019***	3.485***	6.001***			
				(0.315)	(0.498)	(0.709)			
$\ln(Y^{LIC})$							2.955***	3.085***	4.606***
							(0.261)	(0.355)	(0.403)
$\ln(RER)$	-0.102	-0.576**	-0.579**	0.286	-0.782*	-1.286**	0.818***	-0.709*	-0.019
	(0.153)	(0.236)	(0.240)	(0.270)	(0.426)	(0.607)	(0.304)	(0.414)	(0.470)
Method	G:psar1cd	D:l1f0	D:l1f0	D:l1f3	G:psar1cd	D:l1f0	D:l1f3	D:l1f0	D:l1f0

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.5: Results and methods to estimate income elasticities for All Sample by technological intensity (Subsection 2.4.4)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.403***	1.587***	1.770***						
	(0.077)	(0.140)	(0.123)						
$\ln(Y^{HIC})$				1.773***	3.316***	4.810***			
				(0.195)	(0.353)	(0.500)			
$\ln(Y^{LIC})$							2.632***	2.917***	3.927***
							(0.178)	(0.254)	(0.338)
$\ln(RER)$	0.007	-0.979***	-0.733***	0.376**	0.087	0.420	0.745***	-0.038	1.201***
	(0.097)	(0.176)	(0.154)	(0.147)	(0.266)	(0.378)	(0.183)	(0.261)	(0.348)
Method	D:l1f0	D:l1f0	D:l1f0	G:psar1cd	G:psar1cd	D:l1f0	D:l1f0	D:l1f0	D:l1f0

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.6: Results and methods to estimate income elasticities for South America by technological intensity (Subsection 2.4.4)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.710***	1.323***	1.608***						
	(0.161)	(0.158)	(0.211)						
$\ln(Y^{HIC})$				1.352***	0.832***	3.142***			
				(0.143)	(0.149)	(0.33)			
$\ln(Y^{LIC})$							2.109***	1.724***	2.644***
							(0.26)	(0.159)	(0.238)
$\ln(RER)$	0.376***	-0.381***	-1.007***			0.683***	-0.0306	0.178	0.508**
	(0.136)	(0.133)	(0.178)			(0.222)	(0.239)	(0.146)	(0.219)
Method	D:l1f0	D:l1f0	D:l1f0	G:psar1cd	G:psar1cd	D:l1f0	D:l3f0	D:l1f0	D:l1f0

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table B.7: Results and methods to estimate income elasticities for South and East Asia by technological intensity (Subsection 2.4.4)

	$\ln(M^{NR})$	$\ln(M^{CG})$	$\ln(M^{KG})$	$\ln(X^{NR,HIC})$	$\ln(X^{CG,HIC})$	$\ln(X^{KG,HIC})$	$\ln(X^{NR,LIC})$	$\ln(X^{CG,LIC})$	$\ln(X^{KG,LIC})$
$\ln(Y)$	1.421***	1.164***	1.687***						
	(0.118)	(0.089)	(0.12)						
$\ln(Y^{HIC})$				2.000***	2.091***	5.220***			
				(0.151)	(0.118)	(0.596)			
$\ln(Y^{LIC})$							2.263***	2.265***	4.215***
							(0.289)	(0.254)	(0.344)
$\ln(RER)$	-0.687***	-0.367**	-0.623***			-0.528	-0.242	0.422	-0.0996
	(0.196)	(0.147)	(0.199)			(0.510)	(0.337)	(0.296)	(0.401)
Method	D:l1f0	D:l1f0	D:l1f0	G:psar1cd	G:psar1cd	D:l1f0	D:l1f0	D:l1f0	D:l1f0

Methods – (G) Panel GLS, (psar1cd); panel specific AR(1) and CD; (D) Panel Dynamic OLS; (l) number of lags, and (f) number of leadings.
*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Appendix C

Estimation of Verdoorn's law, Chapter 3

Table C.1: Estimation of demand-side Verdoorn's law through Sys-GMM without controls, by industry (Subsection 3.4.1)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.161	0.464***	0.002	0.271	0.346**	0.276	-0.009	-0.013	-0.071	0.123
	(0.174)	(0.179)	(0.072)	(0.473)	(0.136)	(0.203)	(0.154)	(0.020)	(0.105)	(0.173)
y_i	0.722***	0.425***	0.465***	1.023***	0.821***	0.672***	0.797***	0.511***	0.425***	0.530***
	(0.052)	(0.106)	(0.055)	(0.031)	(0.054)	(0.122)	(0.090)	(0.120)	(0.121)	(0.088)
$y_{i,t-1}$	-0.156	-0.247***	-0.0005	-0.275	-0.372***	-0.254*	-0.12	-0.021	-0.063	-0.121
	(0.125)	(0.091)	(0.029)	(0.465)	(0.096)	(0.149)	(0.102)	(0.055)	(0.101)	(0.081)
$(k_i - y_i)$	-0.047	-0.030	-0.020	0.071	0.022	-0.091**	-0.016	-0.0218	-0.018	-0.058***
	(0.040)	(0.062)	(0.025)	(0.055)	(0.022)	(0.041)	(0.015)	(0.056)	(0.065)	(0.0058)
Hansen	2.102	2.859	0.579	4.37	1.763	5.037	1.76	5.324	2.178	3.893
p-value	0.552	0.414	0.901	0.224	0.623	0.169	0.624	0.150	0.536	0.273

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.2: Estimation of demand-side Verdoorn's law through Sys-GMM controlled for schooling, by industry (Subsection 3.4.1)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.138	0.378*	0.001	0.256	0.384***	0.336	-0.009	-0.014	-0.082	0.121
	(0.174)	(0.199)	(0.072)	(0.480)	(0.117)	(0.228)	(0.15)	(0.018)	(0.104)	(0.166)
y_i	0.731***	0.416***	0.471***	1.022***	0.838***	0.694***	0.816***	0.518***	0.433***	0.533***
	(0.054)	(0.106)	(0.057)	(0.031)	(0.056)	(0.139)	(0.097)	(0.124)	(0.123)	(0.087)
$y_{i,t-1}$	-0.132	-0.187*	-0.001	-0.258	-0.403***	-0.318**	-0.114	-0.019	-0.055	-0.117
	(0.128)	(0.010)	(0.027)	(0.473)	(0.077)	(0.161)	(0.099)	(0.054)	(0.098)	(0.078)
$(k_i - y_i)$	-0.0432	-0.028	-0.015	0.0689	0.030	-0.094**	-0.0127	-0.012	-0.013	-0.058***
	(0.041)	(0.067)	(0.02)	(0.055)	(0.022)	(0.044)	(0.012)	(0.054)	(0.066)	(0.006)
H	0.007	0.027**	0.008	0.011	0.008*	0.002	0.017*	0.0268**	0.017	0.001
	(0.008)	(0.012)	(0.007)	(0.031)	(0.005)	(0.018)	(0.009)	(0.012)	(0.015)	(0.011)
Hansen	2.124	2.989	0.585	4.528	2.014	5.215	1.942	5.601	2.262	3.864
p-value	0.547	0.393	0.900	0.210	0.570	0.157	0.585	0.133	0.520	0.277

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.3: Estimation of demand-side Verdoorn's law through Sys-GMM controlled for tech gap, by industry (Subsection 3.4.1)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.119	0.490**	0.007	0.312	0.390***	0.388*	0.006	-0.016	-0.140	0.116
	(0.177)	(0.191)	(0.073)	(0.458)	(0.125)	(0.218)	(0.131)	(0.020)	(0.119)	(0.183)
y_i	0.805***	0.447***	0.464***	1.022***	0.838***	0.701***	0.810***	0.521***	0.482***	0.526***
	(0.042)	(0.094)	(0.076)	(0.025)	(0.062)	(0.139)	(0.083)	(0.126)	(0.102)	(0.0904)
$y_{i,t-1}$	-0.131	-0.259***	0.002	-0.317	-0.413***	-0.361**	-0.141	-0.030	-0.058	-0.098
	(0.130)	(0.092)	(0.030)	(0.451)	(0.084)	(0.150)	(0.087)	(0.053)	(0.090)	(0.085)
$(k_i - y_i)$	0.0285	0.0397	-0.027	0.073	0.037	-0.004	-0.012	0.009	0.094	-0.068***
	(0.024)	(0.081)	(0.048)	(0.048)	(0.037)	(0.0728)	(0.012)	(0.043)	(0.082)	(0.022)
G_i	0.163**	0.244*	0.106	-0.771	0.074	0.101	-0.058	0.575	1.213*	0.483
	(0.081)	(0.145)	(0.097)	(0.535)	(0.143)	(0.144)	(0.070)	(0.974)	(0.691)	(0.704)
Hansen	2.299	1.390	0.536	3.817	2.047	4.842	1.614	5.499	1.913	4.123
p-value	0.513	0.708	0.911	0.282	0.563	0.184	0.656	0.139	0.591	0.248

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.4: Estimation of demand-side Verdoorn's law through Sys-GMM controlled for schooling and tech gap, by industry (Subsection 3.4.1)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.104	0.461**	0.005	0.296	0.384***	0.396*	-0.007	-0.017	-0.152	0.109
	(0.173)	(0.191)	(0.073)	(0.440)	(0.121)	(0.218)	(0.143)	(0.019)	(0.118)	(0.179)
y_i	0.807***	0.457***	0.471***	1.021***	0.845***	0.692***	0.811***	0.526***	0.478***	0.529***
	(0.042)	(0.091)	(0.078)	(0.026)	(0.064)	(0.140)	(0.095)	(0.126)	(0.107)	(0.090)
$y_{i,t-1}$	-0.119	-0.237***	0.001	-0.299	-0.405***	-0.370**	-0.120	-0.027	-0.056	-0.093
	(0.128)	(0.090)	(0.030)	(0.434)	(0.081)	(0.146)	(0.090)	(0.052)	(0.088)	(0.082)
$(k_i - y_i)$	0.0302	0.045	-0.023	0.071	0.042	-0.026	-0.0101	0.012	0.101	-0.071***
	(0.024)	(0.078)	(0.047)	(0.049)	(0.040)	(0.083)	(0.012)	(0.042)	(0.081)	(0.022)
H	0.001	0.022*	0.004	0.015	0.008	0.000	0.016	0.019*	-0.017	-0.007
	(0.010)	(0.011)	(0.008)	(0.027)	(0.0084)	(0.013)	(0.011)	(0.010)	(0.030)	(0.013)
G_i	0.161	0.064	0.098	-0.772	0.0165	0.121	-0.087	0.455	1.551	0.575
	(0.106)	(0.161)	(0.099)	(0.521)	(0.186)	(0.165)	(0.109)	(0.980)	(1.000)	(0.748)
Hansen	2.264	1.401	0.584	3.956	2.073	4.884	2.159	5.547	1.932	4.036
p-value	0.519	0.705	0.900	0.266	0.557	0.181	0.540	0.136	0.587	0.258

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.5: Estimation of supply-side Verdoorn's law through Sys-GMM without controls, by industry (Subsection 3.4.2)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.020	0.503**	0.23	-0.009	0.112	0.0615	0.416***	0.159	-0.170	0.036
	(0.081)	(0.208)	(0.148)	(0.0313)	(0.177)	(0.07)	(0.128)	(0.112)	(0.208)	(0.239)
k_i	-0.034	0.086	-0.071	-0.521	-0.306	-0.062	-0.052	-0.030	-0.383	-0.246**
	(0.258)	(0.182)	(0.206)	(0.521)	(0.287)	(0.172)	(0.187)	(0.178)	(0.236)	(0.115)
$k_{i,t-1}$	0.139	-0.225	0.075*	-0.276	0.232	-0.241*	-0.261	0.049	0.021	-0.018
	(0.139)	(0.157)	(0.044)	(0.878)	(0.17)	(0.145)	(0.234)	(0.189)	(0.176)	(0.123)
l_i	-0.0346	-0.059	0.111***	1.901***	0.0831	0.034	0.046	0.0217	0.211	-0.035**
	(0.069)	(0.153)	(0.029)	(0.165)	(0.119)	(0.091)	(0.0312)	(0.112)	(0.231)	(0.015)
$l_{i,t-1}$	0.054*	0.131	-0.05	-0.002	0.009	0.489***	0.021	0.0397	0.024	0.005
	(0.029)	(0.186)	(0.032)	(0.009)	(0.083)	(0.123)	(0.050)	(0.096)	(0.078)	(0.036)
Hansen	3.062	3.183	1.867	4.816	3.206	2.619	1.028	6.548	7.732	5.966
p-value	0.382	0.364	0.600	0.186	0.361	0.454	0.794	0.088	0.052	0.113

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.6: Estimation of supply-side Verdoorn's law through Sys-GMM controlled for schooling, by industry (Subsection 3.4.2)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.021	0.469**	0.234	-0.019	0.110	0.065	0.316***	0.156	-0.172	0.041
	(0.080)	(0.204)	(0.151)	(0.034)	(0.188)	(0.061)	(0.095)	(0.114)	(0.207)	(0.231)
k_i	-0.047	0.092	-0.076	-0.534	-0.285	-0.014	-0.111	-0.027	-0.397*	-0.231**
	(0.257)	(0.192)	(0.211)	(0.512)	(0.329)	(0.196)	(0.171)	(0.184)	(0.235)	(0.115)
$k_{i,t-1}$	0.118	-0.22	0.076*	-0.357	0.241	-0.341	-0.140	0.043	0.003	-0.017
	(0.136)	(0.161)	(0.044)	(0.875)	(0.178)	(0.214)	(0.192)	(0.191)	(0.178)	(0.128)
l_i	-0.041	-0.075	0.112***	1.882***	0.088	0.0351	0.021	0.023	0.203	-0.035**
	(0.070)	(0.149)	(0.029)	(0.167)	(0.122)	(0.0973)	(0.021)	(0.111)	(0.233)	(0.015)
$l_{i,t-1}$	0.046	0.133	-0.052	-0.005	0.009	0.496***	-0.012	0.043	0.018	0.005
	(0.029)	(0.182)	(0.034)	(0.011)	(0.089)	(0.128)	(0.025)	(0.095)	(0.0812)	(0.036)
H	-0.014	0.006	-0.001	-0.157	0.009	0.010	-0.021	0.007	-0.043	-0.002
	(0.012)	(0.019)	(0.008)	(0.123)	(0.011)	(0.016)	(0.016)	(0.017)	(0.030)	(0.022)
Hansen	3.104	3.355	1.869	4.701	3.38	2.599	0.562	6.517	7.700	5.637
p-value	0.376	0.34	0.6	0.195	0.337	0.458	0.905	0.089	0.0526	0.131

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.7: Estimation of supply-side Verdoorn's law through Sys-GMM controlled for tech gap, by industry (Subsection 3.4.2)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	-0.003	0.396**	0.197	-0.015	0.072	0.080	0.316***	0.119	-0.198	-0.010
	(0.100)	(0.170)	(0.150)	(0.030)	(0.198)	(0.084)	(0.087)	(0.106)	(0.176)	(0.262)
k_i	-0.015	-0.026	-0.084	-0.452	-0.186	-0.072	-0.090	-0.022	-0.417**	-0.242**
	(0.264)	(0.178)	(0.205)	(0.499)	(0.337)	(0.157)	(0.182)	(0.189)	(0.187)	(0.119)
$k_{i,t-1}$	0.121	-0.150	0.065	-0.198	0.260	-0.390*	-0.149	0.086	0.070	0.009
	(0.145)	(0.128)	(0.044)	(0.897)	(0.241)	(0.236)	(0.189)	(0.188)	(0.171)	(0.169)
l_i	0.010	0.194	0.188***	1.890***	0.180	0.124***	0.029*	0.069	0.310***	-0.015
	(0.128)	(0.168)	(0.066)	(0.162)	(0.227)	(0.043)	(0.016)	(0.119)	(0.096)	(0.068)
$l_{i,t-1}$	0.035	-0.061	-0.122**	-0.004	-0.084	0.449*	-0.004	-0.001	-0.054	0.008
	(0.076)	(0.111)	(0.049)	(0.009)	(0.145)	(0.248)	(0.023)	(0.090)	(0.064)	(0.046)
G_i	-0.098	0.0125	-0.062	-1.167	0.184	-0.167	-0.363	-0.355	0.290	0.744
	(0.119)	(0.192)	(0.152)	(1.462)	(0.259)	(0.174)	(0.326)	(1.58)	(0.615)	(1.254)
Hansen	2.899	2.845	1.748	4.912	3.428	1.636	0.85	6.77	7.087	7.758
p-value	0.407	0.416	0.626	0.178	0.330	0.651	0.838	0.0796	0.0692	0.051

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.8: Estimation of supply-side Verdoorn's law through Sys-GMM controlled for schooling and tech gap, by industry (Subsection 3.4.2)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	-0.008	0.395**	0.202	-0.025	0.072	0.075	0.300***	0.118	-0.212	0.001
	(0.101)	(0.171)	(0.154)	(0.032)	(0.195)	(0.090)	(0.085)	(0.105)	(0.180)	(0.256)
k_i	-0.021	-0.017	-0.089	-0.460	-0.181	-0.060	-0.071	-0.025	-0.416**	-0.232*
	(0.257)	(0.183)	(0.209)	(0.485)	(0.337)	(0.16)	(0.178)	(0.189)	(0.184)	(0.119)
$k_{i,t-1}$	0.107	-0.143	0.066	-0.260	0.262	-0.376	-0.153	0.085	0.057	0.005
	(0.142)	(0.129)	(0.045)	(0.895)	(0.244)	(0.233)	(0.182)	(0.188)	(0.17)	(0.165)
l_i	0.001	0.199	0.188***	1.873***	0.179	0.134***	0.025	0.066	0.298***	-0.015
	(0.13)	(0.166)	(0.067)	(0.163)	(0.231)	(0.049)	(0.017)	(0.118)	(0.099)	(0.066)
$l_{i,t-1}$	0.039	-0.060	-0.124**	-0.007	-0.085	0.447*	-0.006	-0.001	-0.059	0.007
	(0.073)	(0.112)	(0.050)	(0.011)	(0.141)	(0.255)	(0.023)	(0.089)	(0.072)	(0.044)
H	-0.017	0.009	0.001	-0.152	-0.003	0.016	-0.0142	0.0020	-0.078**	-0.011
	(0.014)	(0.017)	(0.009)	(0.131)	(0.016)	(0.021)	(0.018)	(0.015)	(0.039)	(0.024)
G_i	-0.007	-0.039	-0.070	-1.023	0.217	-0.249	-0.291	-0.318	1.387	0.856
	(0.144)	(0.202)	(0.156)	(1.56)	(0.339)	(0.205)	(0.327)	(1.602)	(0.93)	(1.257)
Hansen	2.961	2.866	1.778	4.809	3.388	1.675	0.791	6.717	7.321	7.237
p-value	0.398	0.413	0.620	0.186	0.336	0.642	0.852	0.0815	0.0623	0.065

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.9: Estimation of demand-side Verdoorn's law through Sys-GMM not controlled for tech gap, by aggregates (Subsection 3.4.1)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.715***	0.049	0.073	0.181	0.046	0.239	0.678***	0.032	-0.001	0.054	0.104	0.229
	(0.252)	(0.241)	(0.135)	(0.248)	(0.196)	(0.191)	(0.246)	(0.248)	(0.126)	(0.224)	(0.168)	(0.188)
y_i	0.291***	0.523***	0.778***	0.646***	0.646***	0.680***	0.303***	0.534***	0.762***	0.617***	0.653***	0.704***
	(0.0792)	(0.112)	(0.060)	(0.126)	(0.089)	(0.0894)	(0.088)	(0.123)	(0.065)	(0.133)	(0.087)	(0.087)
$y_{i,t-1}$	-0.317***	-0.074	-0.180*	-0.267	-0.151	-0.280**	-0.297***	-0.059	-0.119	-0.165	-0.211*	-0.263**
	(0.112)	(0.0984)	(0.099)	(0.167)	(0.148)	(0.135)	(0.109)	(0.097)	(0.092)	(0.146)	(0.121)	(0.133)
$(k_i - y_i)$	0.004	-0.081***	0.002	0.044*	-0.020	0.015	0.007	-0.076***	0.004	0.035	0.014	0.029
	(0.0347)	(0.014)	(0.039)	(0.027)	(0.066)	(0.053)	(0.040)	(0.016)	(0.033)	(0.025)	(0.060)	(0.050)
H							0.009	0.020*	0.007	0.015*	0.015*	0.019***
							(0.011)	(0.011)	(0.006)	(0.009)	(0.009)	(0.007)
Hansen	0.610	4.092	2.387	2.481	3.393	1.947	0.424	4.541	2.091	2.208	2.803	1.984
p-value	0.894	0.252	0.496	0.479	0.335	0.583	0.935	0.209	0.554	0.530	0.423	0.576

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.10: Estimation of demand-side Verdoorn's law through Sys-GMM controlled for tech gap, by aggregates (Subsection 3.4.1)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.654***	0.047	0.017	0.129	0.061	0.244	0.639***	0.020	-0.019	0.081	0.063	0.219
	(0.244)	(0.276)	(0.143)	(0.253)	(0.219)	(0.175)	(0.236)	(0.268)	(0.135)	(0.225)	(0.213)	(0.178)
y_i	0.419***	0.559***	0.768***	0.619***	0.661***	0.698***	0.437***	0.573***	0.764***	0.622***	0.660***	0.708***
	(0.096)	(0.133)	(0.064)	(0.142)	(0.092)	(0.083)	(0.090)	(0.137)	(0.067)	(0.139)	(0.092)	(0.0827)
$y_{i,t-1}$	-0.362***	-0.098	-0.118	-0.213	-0.189	-0.284**	-0.353***	-0.086	-0.090	-0.180	-0.190	-0.261**
	(0.115)	(0.115)	(0.108)	(0.178)	(0.144)	(0.127)	(0.112)	(0.108)	(0.099)	(0.155)	(0.14)	(0.129)
$(k_i - y_i)$	0.194**	-0.020	-0.002	0.036	0.043	0.022	0.196***	-0.013	-0.003	0.038	0.042	0.036
	(0.081)	(0.080)	(0.039)	(0.029)	(0.062)	(0.055)	(0.073)	(0.080)	(0.038)	(0.025)	(0.064)	(0.0527)
H							0.010	0.013	0.001	0.014	0.000	0.018*
							(0.011)	(0.013)	(0.008)	(0.010)	(0.010)	(0.010)
G_i	0.095	0.676	0.200	0.145	0.647**	0.109	0.041	0.506	0.219	0.049	0.660*	-0.003
	(0.164)	(0.460)	(0.127)	(0.191)	(0.318)	(0.077)	(0.163)	(0.541)	(0.144)	(0.190)	(0.396)	(0.119)
Hansen	2.075	5.356	2.416	2.882	2.726	0.860	1.539	5.544	2.545	2.493	2.758	1.015
p-value	0.557	0.148	0.491	0.410	0.436	0.835	0.673	0.136	0.467	0.477	0.430	0.798

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.11: Estimation of supply-side Verdoorn's law through Sys-GMM not controlled for tech gap, by aggregates (Subsection 3.4.2)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.589***	0.620***	0.248	0.191	0.366	0.276	0.588***	0.618***	0.162	0.130	0.324	0.270
	(0.158)	(0.238)	(0.168)	(0.231)	(0.352)	(0.288)	(0.156)	(0.240)	(0.146)	(0.216)	(0.378)	(0.288)
k_i	-0.092	-0.220	-0.339*	-0.284*	-0.313	-0.316	-0.099	-0.218	-0.322	-0.278*	-0.304	-0.316
	(0.110)	(0.152)	(0.202)	(0.162)	(0.239)	(0.381)	(0.107)	(0.154)	(0.201)	(0.16)	(0.247)	(0.378)
$k_{i,t-1}$	-0.049	0.082	0.256	-0.019	0.363***	0.008	-0.050	0.084	0.273	0.030	0.329**	0.008
	(0.075)	(0.114)	(0.211)	(0.141)	(0.134)	(0.320)	(0.075)	(0.116)	(0.206)	(0.126)	(0.137)	(0.318)
l_i	-0.057	-0.040	0.004	0.066	0.046	0.120	-0.061	-0.039	-0.013	0.043	0.057	0.120
	(0.084)	(0.051)	(0.057)	(0.082)	(0.104)	(0.141)	(0.084)	(0.051)	(0.054)	(0.077)	(0.110)	(0.138)
$l_{i,t-1}$	0.020	0.017	0.131	0.083	-0.066	0.009	0.014	0.017	0.077	0.041	-0.053	0.011
	(0.054)	(0.023)	(0.087)	(0.058)	(0.067)	(0.046)	(0.057)	(0.024)	(0.048)	(0.029)	(0.062)	(0.046)
H							-0.006	0.004	-0.015	-0.010	0.005	-0.001
							(0.011)	(0.014)	(0.014)	(0.013)	(0.014)	(0.013)
Hansen	0.544	3.854	2.094	2.145	4.442	6.065	0.525	3.857	1.968	1.912	4.583	5.953
p-value	0.909	0.278	0.553	0.543	0.218	0.108	0.913	0.277	0.579	0.591	0.205	0.114

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.12: Estimation of supply-side Verdoorn's law through Sys-GMM controlled for tech gap, by aggregates (Subsection 3.4.2)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.496***	0.380	0.163	0.119	0.283	0.211	0.499***	0.379	0.151	0.115	0.282	0.205
	(0.157)	(0.276)	(0.144)	(0.224)	(0.437)	(0.282)	(0.157)	(0.275)	(0.151)	(0.226)	(0.437)	(0.281)
k_i	-0.114	-0.262*	-0.377*	-0.340**	-0.232	-0.314	-0.113	-0.263*	-0.363*	-0.334**	-0.232	-0.303
	(0.108)	(0.138)	(0.199)	(0.162)	(0.280)	(0.385)	(0.105)	(0.139)	(0.204)	(0.163)	(0.277)	(0.386)
$k_{i,t-1}$	-0.099	0.152	0.244	-0.001	0.358***	-0.026	-0.105	0.153	0.240	-0.002	0.356***	-0.026
	(0.081)	(0.153)	(0.223)	(0.134)	(0.128)	(0.320)	(0.082)	(0.152)	(0.225)	(0.135)	(0.126)	(0.317)
l_i	0.149	0.187*	-0.004	0.050	0.092	0.176	0.148	0.186*	-0.005	0.051	0.095	0.178
	(0.12)	(0.112)	(0.058)	(0.080)	(0.094)	(0.164)	(0.123)	(0.112)	(0.056)	(0.080)	(0.090)	(0.163)
$l_{i,t-1}$	-0.066	-0.090	0.073	0.036	-0.102**	-0.006	-0.065	-0.090	0.072	0.038	-0.101**	-0.004
	(0.043)	(0.069)	(0.050)	(0.029)	(0.047)	(0.049)	(0.041)	(0.069)	(0.051)	(0.030)	(0.048)	(0.049)
H							-0.004	-0.001	-0.004	0.002	0.003	0.005
							(0.012)	(0.017)	(0.015)	(0.013)	(0.022)	(0.013)
G_i	-0.004	0.643	-0.440**	-0.437**	0.234	-0.153	0.030	0.674	-0.410**	-0.446**	0.169	-0.172
	(0.157)	(0.773)	(0.213)	(0.22)	(0.824)	(0.154)	(0.157)	(0.897)	(0.209)	(0.199)	(1.109)	(0.178)
Hansen	0.287	5.626	2.429	2.085	4.286	4.954	0.235	5.644	2.375	2.099	4.259	5.011
p-value	0.962	0.131	0.488	0.555	0.232	0.175	0.972	0.130	0.498	0.552	0.235	0.171

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.13: Estimation of Verdoorn's law through Sys-GMM without controls (heterogeneous), by industry (Section 3.5)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.205	0.489**	0.045	0.338	0.417***	0.366*	-0.025	-0.006	0.008	0.143
	(0.193)	(0.200)	(0.095)	(0.450)	(0.094)	(0.219)	(0.157)	(0.048)	(0.117)	(0.154)
y_i	0.758***	2.417***	0.839*	2.024**	1.111***	1.042**	1.784***	1.183	1.387***	1.122
	(0.284)	(0.528)	(0.495)	(0.985)	(0.407)	(0.450)	(0.570)	(1.337)	(0.399)	(0.847)
$y_{i,t-1}$	0.305	-0.642	-0.345	-0.659	-0.676	-0.457*	-0.603*	0.046	-1.347***	-0.079
	(0.266)	(0.432)	(0.233)	(0.856)	(0.435)	(0.244)	(0.339)	(0.768)	(0.494)	(0.300)
$y_i \ln(Ypc)$	-0.003	-0.229***	-0.043	-0.118	-0.029	-0.036	-0.106*	-0.074	-0.111**	-0.068
	(0.034)	(0.062)	(0.055)	(0.113)	(0.041)	(0.057)	(0.064)	(0.124)	(0.050)	(0.100)
$y_{i,t-1} \ln(Ypc)$	-0.056*	0.043	0.036	0.037	0.027	0.012	0.052*	-0.007	0.136**	-0.006
	(0.033)	(0.045)	(0.026)	(0.058)	(0.047)	(0.017)	(0.031)	(0.075)	(0.055)	(0.031)
$(k_i - y_i)$	-0.042	0.051	-0.040	0.027	0.020	-0.072*	-0.017	-0.039	-0.002	-0.057***
	(0.037)	(0.059)	(0.053)	(0.061)	(0.025)	(0.039)	(0.015)	(0.061)	(0.048)	(0.006)
Hansen	2.154	7.857	0.704	5.252	1.821	4.745	1.458	5.791	2.751	3.933
p-value	0.541	0.049	0.872	0.154	0.610	0.191	0.692	0.122	0.432	0.269

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.14: Estimation of Verdoorn's law through Sys-GMM controlled for schooling (heterogeneous), by industry (Section 3.5)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.176	0.431**	0.038	0.304	0.383***	0.370*	-0.021	-0.005	-0.007	0.136
	(0.186)	(0.209)	(0.095)	(0.448)	(0.096)	(0.222)	(0.160)	(0.048)	(0.120)	(0.147)
y_i	0.827***	2.351***	0.860*	2.032**	1.218***	1.106**	2.359***	1.288	1.449***	1.158
	(0.279)	(0.527)	(0.500)	(0.967)	(0.378)	(0.453)	(0.467)	(1.297)	(0.378)	(0.873)
$y_{i,t-1}$	0.492*	-0.636	-0.308	-0.590	-0.485	-0.391*	-0.652**	0.121	-1.268**	-0.033
	(0.298)	(0.414)	(0.250)	(0.874)	(0.442)	(0.217)	(0.294)	(0.788)	(0.503)	(0.308)
$y_i \ln(Ypc)$	-0.010	-0.220***	-0.044	-0.119	-0.039	-0.043	-0.166***	-0.084	-0.117**	-0.071
	(0.034)	(0.064)	(0.056)	(0.111)	(0.038)	(0.056)	(0.052)	(0.121)	(0.048)	(0.103)
$y_{i,t-1} \ln(Ypc)$	-0.074**	0.047	0.032	0.033	0.010	0.004	0.058**	-0.014	0.128**	-0.011
	(0.034)	(0.043)	(0.027)	(0.060)	(0.048)	(0.015)	(0.026)	(0.077)	(0.055)	(0.032)
$(k_i - y_i)$	-0.034	0.055	-0.036	0.025	0.025	-0.0781*	-0.008	-0.028	0.004	-0.056***
	(0.038)	(0.061)	(0.053)	(0.061)	(0.025)	(0.042)	(0.012)	(0.057)	(0.049)	(0.006)
H	0.012	0.016	0.008	0.017	0.012*	0.006	0.029***	0.037**	0.012	0.008
	(0.009)	(0.012)	(0.007)	(0.034)	(0.006)	(0.011)	(0.009)	(0.015)	(0.014)	(0.011)
Hansen	2.206	8.093	0.795	5.481	1.538	4.720	1.698	5.900	2.800	3.996
p-value	0.531	0.044	0.851	0.140	0.674	0.193	0.637	0.117	0.424	0.262

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.15: Estimation of Verdoorn's law through Sys-GMM controlled for tech gap (heterogeneous), by industry (Section 3.5)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.170	0.510***	0.057	0.368	0.405***	0.419	-0.015	-0.010	-0.108	0.136
	(0.193)	(0.175)	(0.080)	(0.488)	(0.106)	(0.255)	(0.147)	(0.068)	(0.133)	(0.163)
y_i	1.073***	2.227***	1.258**	1.963**	1.249***	0.296	2.172***	1.102	1.400***	1.296
	(0.267)	(0.473)	(0.57)	(0.937)	(0.450)	(0.621)	(0.509)	(1.775)	(0.363)	(0.790)
$y_{i,t-1}$	0.377	-0.548	-0.573**	-0.762	-0.564	-0.095	-0.686**	0.028	-1.046*	0.039
	(0.285)	(0.428)	(0.258)	(0.914)	(0.529)	(0.513)	(0.300)	(1.132)	(0.543)	(0.331)
$y_i \ln(Ypc)$	-0.031	-0.205***	-0.083	-0.112	-0.042	0.046	-0.147***	-0.064	-0.106**	-0.087
	(0.032)	(0.056)	(0.059)	(0.109)	(0.045)	(0.077)	(0.056)	(0.169)	(0.044)	(0.094)
$y_{i,t-1} \ln(Ypc)$	-0.062*	0.032	0.058**	0.045	0.016	-0.029	0.059**	-0.006	0.106*	-0.017
	(0.033)	(0.045)	(0.027)	(0.058)	(0.055)	(0.062)	(0.027)	(0.112)	(0.060)	(0.033)
$(k_i - y_i)$	0.033	0.089	-0.021	0.017	0.029	-0.007	-0.012	-0.014	0.096	-0.062***
	(0.022)	(0.102)	(0.055)	(0.060)	(0.038)	(0.078)	(0.013)	(0.041)	(0.073)	(0.024)
G_i	0.204**	0.082	0.119	-0.843*	0.129	0.130	-0.074	0.682	1.103	0.745
	(0.083)	(0.163)	(0.102)	(0.491)	(0.156)	(0.136)	(0.083)	(0.973)	(0.798)	(0.661)
Hansen	2.276	5.440	0.478	4.744	1.690	4.750	1.160	5.654	2.490	4.447
p-value	0.517	0.142	0.924	0.192	0.639	0.191	0.763	0.130	0.477	0.217

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.16: Estimation of Verdoorn's law through Sys-GMM controlled for schooling and tech gap (heterogeneous), by industry (Section 3.5)

	q_{Food}	$q_{Textiles}$	q_{Paper}	q_{Fuels}	$q_{Chemicals}$	$q_{Non-Met.}$	q_{Metals}	$q_{Machinery}$	$q_{Transport}$	q_{Others}
$q_{i,t-1}$	0.151	0.464***	0.052	0.338	0.386***	0.428	-0.045	-0.009	-0.115	0.119
	(0.187)	(0.172)	(0.077)	(0.46)	(0.103)	(0.265)	(0.165)	(0.069)	(0.128)	(0.162)
y_i	1.102***	2.125***	1.351**	1.974**	1.241***	0.336	2.366***	1.203	1.367***	1.298
	(0.260)	(0.466)	(0.608)	(0.923)	(0.450)	(0.618)	(0.507)	(1.748)	(0.353)	(0.816)
$y_{i,t-1}$	0.411	-0.538	-0.586**	-0.699	-0.475	-0.148	-0.556*	0.105	-1.057**	0.069
	(0.293)	(0.381)	(0.257)	(0.872)	(0.534)	(0.476)	(0.313)	(1.148)	(0.512)	(0.328)
$y_i \ln(Ypc)$	-0.034	-0.192***	-0.092	-0.113	-0.040	0.040	-0.167***	-0.074	-0.102**	-0.086
	(0.032)	(0.057)	(0.062)	(0.107)	(0.046)	(0.076)	(0.055)	(0.166)	(0.042)	(0.097)
$y_{i,t-1} \ln(Ypc)$	-0.064**	0.034	0.059**	0.041	0.008	-0.025	0.049*	-0.013	0.106*	-0.019
	(0.033)	(0.041)	(0.027)	(0.056)	(0.056)	(0.060)	(0.028)	(0.114)	(0.058)	(0.033)
$(k_i - y_i)$	0.0365*	0.096	-0.016	0.016	0.036	-0.029	-0.008	-0.011	0.102	-0.063***
	(0.021)	(0.091)	(0.054)	(0.060)	(0.04)	(0.087)	(0.013)	(0.041)	(0.073)	(0.023)
H	0.006	0.022*	0.006	0.021	0.010	-0.002	0.032***	0.029**	-0.019	0.000
	(0.010)	(0.013)	(0.008)	(0.032)	(0.009)	(0.012)	(0.012)	(0.013)	(0.027)	(0.014)
G_i	0.179*	-0.099	0.115	-0.850*	0.060	0.158	-0.159	0.455	1.420	0.828
	(0.102)	(0.191)	(0.107)	(0.495)	(0.193)	(0.169)	(0.142)	(0.924)	(1.051)	(0.696)
Hansen	2.219	5.358	0.588	4.943	1.634	4.832	1.879	5.648	2.556	4.389
p-value	0.528	0.147	0.899	0.176	0.652	0.185	0.598	0.130	0.465	0.222

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.17: Estimation of Verdoorn's law through Sys-GMM not controlled for tech gap (heterogeneous), by aggregates (Section 3.5)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.709**	0.007	0.147	0.192	0.232	0.221	0.638**	-0.020	0.103	0.108	0.208	0.159
	(0.303)	(0.22)	(0.153)	(0.262)	(0.193)	(0.159)	(0.302)	(0.227)	(0.138)	(0.237)	(0.188)	(0.169)
y_i	1.581***	0.707	1.767***	1.160	1.534**	2.098*	1.666***	0.834*	1.927***	1.702	1.553**	2.127*
	(0.590)	(0.456)	(0.288)	(1.142)	(0.637)	(1.102)	(0.553)	(0.443)	(0.264)	(1.168)	(0.633)	(1.133)
$y_{i,t-1}$	-0.952**	-0.713	-0.455	-0.560	-1.354**	-0.845**	-0.917**	-0.629	-0.149	-0.358	-1.220**	-0.522
	(0.473)	(0.465)	(0.405)	(0.769)	(0.53)	(0.412)	(0.423)	(0.495)	(0.367)	(0.657)	(0.552)	(0.394)
$y_i \ln(Ypc)$	-0.145**	-0.018	-0.115***	-0.060	-0.089	-0.159	-0.151***	-0.031	-0.131***	-0.117	-0.091	-0.160
	(0.063)	(0.049)	(0.037)	(0.123)	(0.064)	(0.123)	(0.059)	(0.046)	(0.035)	(0.123)	(0.063)	(0.126)
$y_{i,t-1} \ln(Ypc)$	0.069	0.070	0.026	0.034	0.114*	0.064	0.069*	0.063	-0.003	0.020	0.101*	0.034
	(0.044)	(0.050)	(0.043)	(0.083)	(0.059)	(0.045)	(0.039)	(0.053)	(0.038)	(0.07)	(0.059)	(0.041)
$(k_i - y_i)$	0.035	-0.069***	0.005	0.029	0.026	-0.015	0.048	-0.064***	0.019	0.032	0.032	0.014
	(0.045)	(0.017)	(0.050)	(0.037)	(0.051)	(0.073)	(0.045)	(0.018)	(0.033)	(0.032)	(0.053)	(0.054)
H							0.015	0.018	0.017**	0.025**	0.011	0.027***
							(0.013)	(0.011)	(0.007)	(0.011)	(0.009)	(0.009)
Hansen	3.180	2.877	3.771	3.451	2.325	1.658	2.498	3.454	3.103	3.134	2.202	1.786
p-value	0.365	0.411	0.287	0.327	0.508	0.646	0.476	0.327	0.376	0.371	0.532	0.618

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.

Table C.18: Estimation of Verdoorn's law through Sys-GMM controlled for tech gap (heterogeneous), by aggregates (Section 3.5)

	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}	q_{CG}	q_{KG}	q_{NR}	q_{LT}	q_{HT}	q_{Manuf}
$q_{i,t-1}$	0.703**	-0.022	0.181	0.256	0.144	0.219	0.641**	-0.064	0.112	0.157	0.148	0.164
	(0.29)	(0.253)	(0.156)	(0.262)	(0.248)	(0.158)	(0.288)	(0.238)	(0.145)	(0.229)	(0.238)	(0.163)
y_i	1.760***	0.838*	1.861***	1.385	1.414**	2.118*	1.826***	0.922**	1.951***	1.782	1.409**	2.119*
	(0.531)	(0.463)	(0.283)	(1.304)	(0.667)	(1.149)	(0.475)	(0.441)	(0.269)	(1.23)	(0.666)	(1.104)
$y_{i,t-1}$	-1.243**	-0.792*	-0.286	-0.493	-0.875	-0.635	-1.208***	-0.735	-0.105	-0.333	-0.867	-0.551
	(0.549)	(0.476)	(0.420)	(0.840)	(0.605)	(0.434)	(0.439)	(0.497)	(0.368)	(0.689)	(0.615)	(0.422)
$y_i \ln(Ypc)$	-0.146***	-0.027	-0.123***	-0.081	-0.077	-0.159	-0.150***	-0.035	-0.133***	-0.124	-0.076	-0.158
	(0.057)	(0.049)	(0.037)	(0.139)	(0.066)	(0.128)	(0.051)	(0.047)	(0.036)	(0.129)	(0.066)	(0.123)
$y_{i,t-1} \ln(Ypc)$	0.091*	0.077	0.007	0.025	0.068	0.041	0.0900**	0.072	-0.007	0.014	0.067	0.036
	(0.054)	(0.052)	(0.044)	(0.091)	(0.062)	(0.045)	(0.044)	(0.054)	(0.038)	(0.073)	(0.064)	(0.044)
$(k_i - y_i)$	0.254*	0.009	0.009	0.030	0.044	0.009	0.266**	0.017	0.017	0.034	0.043	0.022
	(0.136)	(0.068)	(0.048)	(0.042)	(0.058)	(0.064)	(0.109)	(0.069)	(0.036)	(0.033)	(0.06)	(0.057)
H							0.017	0.009	0.014	0.024**	-0.001	0.0217*
							(0.013)	(0.015)	(0.009)	(0.011)	(0.011)	(0.011)
G_i	0.016	0.554	0.186	0.216	0.594	0.229	-0.059	0.497	0.126	0.066	0.604	0.090
	(0.178)	(0.424)	(0.138)	(0.198)	(0.364)	(0.140)	(0.171)	(0.505)	(0.147)	(0.188)	(0.448)	(0.148)
Hansen	5.374	3.892	3.951	4.148	2.155	1.038	4.107	4.132	3.481	3.432	2.183	0.950
p-value	0.146	0.273	0.267	0.246	0.541	0.792	0.250	0.248	0.323	0.330	0.535	0.813

*: significant at the 10% level; **:significant at the 5% level; ***:significant at the 1% level.